Sheldons'

SUPPLEMENTARY

READING

THIRD BOOK

Butler, Sheldon & Co.

PREFACE

THIS book is intended to follow the use of any Third Reader. It is believed that if pupils have been properly taught, they can take up this book without difficulty at this stage. With the exception of a few scientific terms, there are very few words so difficult as to be any hindrance to its use. These can be made as easy as any others by a little care on the part of the teacher. It is important that children be early taught to observe what they see around them; to notice some of the more common phenomena with which they are surrounded; and also to express their observations in something like accurate language.

The language of science, for such purposes, is always the simplest, and the most easily comprehended.

The questions appended to the several lessons are merely suggestive, and many others should be used by the teacher in reviewing each lesson.

It is believed that children will not only learn much that will be valuable for them to know, from a proper use of this

book, but also that their interest will be so enlisted that they will also *learn to read* much more rapidly than they are likely to do by using an additional book of disconnected *selections.*

Great care should be taken to be sure that the children thoroughly understand every statement of fact, and so far as may be possible, to make experiments.

While this little book is not intended as a text-book on Physical Science, the elements of science may be, and should be, mastered by its use. The habit of careful and accurate observation can be easily secured, and nothing, in the training of children, can be of greater importance.

With the hope that curiosity,—that potent factor in education,—may be aroused, and correct habits of observation secured, this little volume is submitted to the teachers of the country by

THE AUTHOR.

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SHELDONS'

SUPPLEMENTARY READING.

LESSON I.

SUNBEAMS.

I.

1. In order to learn science, we must learn something of the language of science. If you were to travel in a country without knowing the language of that country, you would learn but a small part of that which you might learn if you could talk with the people whom you met. So, if you are to go to books to find answers to your questions, you must know something of the language used in books. You need not learn very many hard names, but you must clearly understand what common words mean.

2. And more than this, you must keep your eyes open all the time. There are many more things to be seen about us than most of us ever see. There is very much of interest to be learned about the most common things of every-day life. Who does not love the

sunbeam? It is so dear to us, that it has become a household word for all that is bright and cheerful. When we wish to describe the happiest little girl among us, who brings a smile to every face, wherever she goes, we call her "the sunbeam of the house."

3. And yet, how little even the wisest among us know about the nature and work of these bright sunbeams, which come every day to gladden our lives. Did you ever wake quite early in the morning, when it was still dark, and you could see nothing, not even your own hand; and then lie waiting and watching, until the light came slowly creeping in at the window?

4. At first you can only see the dim outline of the things in the room. Then, by degrees, the form of the objects in the room becomes clearer and clearer, until at last you see all, distinctly, in broad daylight. What has been happening here? Why have the things in the room become visible by such slow degrees? We say the sun is rising, but we know very well it is not the sun that moves. Our earth has been turning slowly round, until the little spot on which we live has been brought face to face with the sun, so that its beams can fall upon us.

5. Take a small globe, and place a piece of paper over that part of it on which you find the map of the United States. Let a lighted lamp represent the sun.

Then turn the globe slowly, so that the paper moves away from the lamp, and round the dark side. As the globe turns, the paper comes again into the light. It catches, first, the rays which pass along the side of the globe, and at last it comes into the full blaze of the light from the lamp. This is just what was happening to our spot of the earth, as you lay in bed, and saw the daylight slowly come.

6. What are these little beams of light? They all come from the sun. If the sun were a dark mass instead of a fiery one, we should have none of these bright rays. Over the whole earth, it would always be one cold, eternal night. Think how bitterly cold it would be—far colder than the coldest weather ever known in winter. Indeed, if we never received any warmth at all from the sun, our earth would be one great, frozen mass, with nothing moving or living upon it.

7. So you see it will be of interest for us to learn what the sun is, and how it sends us its beams. How far away from us do you think the sun is? On a fine summer's day, when we can see it clearly in the sky, it looks as though we might get into a balloon and soon reach it. Yet we know that the sun is almost ninety-three millions of miles distant from our earth.

8. Ninety-three millions of miles! The mind can form no idea of so large a number. Few railway

trains go as fast as thirty miles an hour. But sometimes they go, for short distances, sixty miles an hour, or a mile a minute. Imagine yourself in an express train traveling at the rate of sixty miles an hour, and never stopping night or day. It would require one hundred and seventy-seven years to make the journey to the sun in such a train.

9. And when you reached the sun, how large do you think you would find it to be? The earth measures about eight thousand miles through its center, and about twenty-five thousand miles around it, at the equator. Yet it would require thirteen hundred thousand worlds, the size of our earth, to make one as large as the sun.

10. Or, imagine for a moment that you could cut the sun and the earth in halves, as you can cut an apple. Then, if you were to lay the flat side of the half-earth on the flat side of the half-sun it would take one hundred and nine half-earths to stretch across the face of the sun. These would be so small, compared with the sun, that they would look like a string of little beads stretched across its face.

1. What is the source of the sunbeams?

2. If the sun were a dark mass, would there be any light on the earth?

3. What would the earth be without the sun?

4. How far away is the sun?

5. How long would it take an express train, running at the rate of a mile a minute, to go to the sun?

6. How many worlds the size of our earth would make one as large as the sun?

LESSON II.

SUNBEAMS.

II.

1. In order to see how powerful the sunbeams are, you have only to take a common magnifying glass, and gather them to a point on a piece of brown paper. You will find that they will set the paper on fire. Sir John Herschel tells us that, at the Cape of Good Hope, the sun's heat was so great that he even cooked a beef-steak, and roasted some eggs, by merely putting them in the sun, in a box with a glass lid.

2. Indeed, just as we should all be frozen to death if the sun were cold, so we should all be burned up by the heat, if its fierce rays fell with all their might upon us. But we have an invisible veil protecting us, made—of what do you think? Of the water-vapor which the sunbeams draw up, and scatter through the air. This keeps off from us part of the intense heat, and makes the air cool and pleasant.

3. When you think of the great size of the sun, and

remember that it is a huge globe, made of fiery matter, you will not be astonished that it gives out such a vast quantity of heat and light. The amount is so vast, indeed, that it is almost impossible to form any idea of it. The light of the sun is the brightest light known to man. It is three or four times as bright as the best electric light. The brightest light man has been able to produce, seems dim and weak compared with the light of the sun.

4. Perhaps we get the best idea of the mighty heat and light of the sun by thinking how few of all the rays which dart out on every side from this fiery ball reach our earth, and yet how powerful those that do reach us are. Look at a lamp in the middle of a room, and see how its light streams out on all sides, and into every corner of the room. Then take a common pin, the head of which will, for this purpose, very well represent the size of the earth, and hold it up at a distance from the lamp.

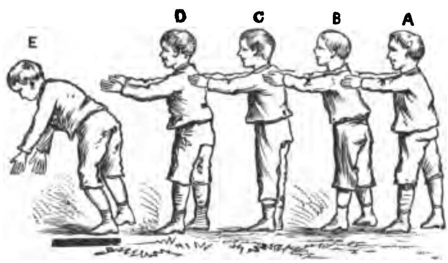
5. How very few of all the rays that are streaming out from the lamp, and filling the room, fall on the head of the pin. Just as few of the countless rays that dart out from the sun fall upon our earth. And yet this small portion of the sun's light and heat not only warms and lights the whole earth, but it does nearly all the work of this busy world.

6. We have learned something of the distance, the

size, the light, and the heat of the sun—the source of the sunbeams. But we have not yet found the answer to the question, What is a sunbeam?

Did you ever throw a pebble upon the smooth surface of a pond, and watch the ripples of water, circling out in larger and wider circles, one after the other, until they reached the shore?

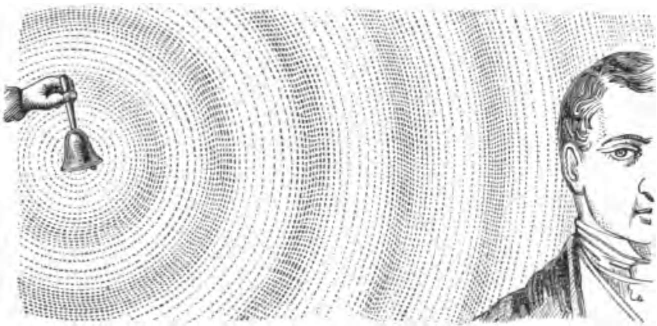
7. As the pebble struck the water, little waves were formed, and these passed along the surface of the pond until they could go no farther. If you speak to a playmate, how does the sound of your voice reach his ear? When you speak, you move the air near your mouth, and that makes a wave in the air beyond. That wave makes another, and another, and the last wave hits the drum of your playmate's ear.



8. Perhaps an illustration of the way in which the waves of sound move, will help us to imagine how light can move in waves. Here is a picture of some boys, which Professor Tyndall uses as an illustration, and this is what he says about it: "I suddenly push A; A pushes B, and regains his upright position; B pushes C; C pushes D; D pushes E; each boy, after passing along

the push, becoming himself erect. E, having no boy in front of him, is thrown forward.

9. "Had E been standing on the edge of a precipice he would have fallen over. Had he been close to a drum-head he would have shaken the drum. We could thus transmit a push through a row of a hundred boys, each particular boy, however, only swaying to and fro. In this way we send sound through the air, and shake the drum of a distant ear."



10. We have here a picture of a bell, and the waves of sound which the ringing bell makes. This will show you how the sound of a bell moves the layers of air between itself and the drum of the ear of a person who hears the bell.

1. How can we show the power of the sunbeams?
2. What protects us from the fierce heat of the sun's rays?
3. What would happen if we felt the full power of the sun's rays?
4. How does the sound of your voice reach the ear of a person?

LESSON III.

WHAT THE SUNBEAMS ARE.

I.

1. Two hundred years ago there lived in England a famous natural philosopher, Sir Isaac Newton. In all the history of science there is no greater name than that of Newton. But few of the wisest men of his time could follow where he led in searching out the hidden things of nature. The wisest men since his day have been glad to walk in Newton's footsteps, through paths in which he was the first to tread.

2. This famous scholar thought that the sunbeams were made of very small atoms of matter, which are thrown off by the sun. It is easy to understand how this would make us see light and feel heat. Many people thought this was the right answer to our question. But we now know there are some facts which cannot be explained by Newton's theory of light. There is another explanation of the sunbeam, which seems to be the right one.

3. A Dutchman, named Huyghens, who lived in the time of Newton, suggested that light comes from the sun in tiny waves, which travel through space in much the same way that ripples travel across a pond. The only difficulty was to find out in what substance

these waves move. It cannot be in water, for we know there is no water in space. Nor can they move in air, for the air stops about a hundred miles from the earth. There must, then, be something finer than either water or air, filling all the space between the earth and the sun.

4. We cannot see the air, yet we know there is such a substance. We can see and feel its effects, and in this way we learn that it is all about us. So there is a fine, delicate substance filling all the space between our earth and the sun and stars. We can neither see it nor touch it, but we know it by its effects. It is so very fine and thin that we cannot see it, but it can pass through solid bodies such as glass, ice, or even wood and brick walls.

5. We call this delicate substance, *ether*. Some time, perhaps, you may learn the reasons why men think there is such a substance in space. Until you can study the question for yourself, you must take the fact of its being there on the word of the wise men who have studied it. Try to imagine this ether as filling every part of space, so that it is everywhere, and passes through everything.

6. Now ask yourself, What must happen when any great commotion is going on in one of the large bodies which float in space? When the atoms of the gas that forms the body of the sun are clashing together to

make all the light and heat of the sun, do you not think they must shake the ether all about them? And since this ether stretches, on every side, from the sun to our earth and all the stars, must not this motion travel to us just as the ripples travel across the water to the edge of the pond?

7. The waves of light travel over the ether to the earth in just this way. Straight away from the sun, on all sides, never stopping, never loitering, but following each other with wonderful quickness, the tiny sunbeams dart out into space by night and by day. When our spot of the earth is turned away from the sun, they cannot reach us, and it is night for us. But when we face the sun, its beams strike on the land, and the water, and warm them; or they touch our eyes and make the nerves quiver so that we see light.

1. What did Newton think the sunbeams are?
2. Who first suggested the right explanation of the sunbeams?
3. What is the substance in which the waves of light move?
4. How do we know there is such a substance in space?

LESSON IV.

WHAT THE SUNBEAMS ARE.

II.

1. When the daylight is gone, if the night is clear, we have light from the stars. Do the stars, too, make waves across the vast distance between them and us? Certainly they do. Some of the stars are suns like our own. They give out light and heat as the sun does, and many of them must be larger and brighter than our sun. But they are so far away that the waves they send are very feeble, and so we only notice them when the sun's stronger waves do not reach us.

2. Perhaps you will ask, if no one has ever seen any of these waves, nor the ether in which they are made, what right have we to say they are there? Strange as it may seem, though we cannot see them they have been measured. We know how large they are, and how many can go into an inch of space.

3. How large do you suppose they are? So very, very small that about fifty thousand of them are contained in a single inch of space. Hold your thumb and finger in the air, an inch apart. Within that narrow space, at this moment there are fifty thousand tiny waves of light moving up and down! There are

many things to be learned in science as wonderful as anything you can find in fairy tales.

4. How fast do these little waves travel? You remember that an express train would take one hundred and seventy-seven years to come to the earth from the sun. Even a cannon-ball would take about thirteen years to come that distance. But these little waves take only eight minutes to come the whole ninety-three million miles. The waves that are entering your eye at this moment were caused by a movement which began at the sun only eight minutes ago.

5. This rapid movement is going on all the time. These waves follow one after the other so fast, that, in daylight, they are always striking the pupil of the eye. An immense number of them enter the eye in a single second.

So far we have spoken of the sunbeam as if it were made of only one set of waves. But in truth it is made of many sets of waves, of different sizes, all coming together from the sun.

6. These different waves have been measured. We know that the waves which make up red light are larger than those which make violet light. There are only thirty-nine thousand red waves in an inch of space, while there are fifty-seven thousand violet waves in the same space. If all the waves that make the different colors strike our eye, why do we not always see colored

light? Because all the colors, mixed together in proper proportion, make a white color.

7. Light looks white to us because all the different waves strike on our eye at once. But why do the rapid little waves make us see one color, and the slow, heavy waves another? This is a very hard question to answer. We have still much to learn about the way in which light acts on the eye. Perhaps color affects our eye in much the same way that music affects the ear.

8. We distinguish different notes, or musical sounds, when the air-waves strike slowly or quickly upon the drum of the ear. In somewhat the same way the little waves of ether strike on the curtain in the back part of the eye, called the *retina*, and make the nerves carry different messages to the brain. The color we see depends upon the number of waves which strike upon the retina of the eye in a second.

9. Do you think we have now found the answer to the question—What is a sunbeam? We have seen that it is really a succession of rapid, little, waves that come from the sun to us across the fine, invisible substance which we call ether. We have also seen that, small and delicate as these waves are, they can still differ in size.

10. A single sunbeam is made up of a vast number of waves of different size. When all these waves strike the eye at the same time, they make us see

white light. If for any reason they are separated, so that they touch the eye one at a time, we see them as red, orange, yellow, green, blue, indigo, or deep blue, and violet rays. How they become separated, and many other secrets of the sunbeams, you can learn when you are older.

1. Why do we not see the stars during the daylight?
2. How many waves of light are there in an inch of space?
3. How long do the light-waves take to come from the sun to the eye?
4. Why does light appear white to us?
5. What is a sunbeam?
6. When do we see the different colors in a ray of light?

LESSON V.

THE WORK OF THE SUNBEAMS.

I.

1. What work do the sunbeams do for us? They do two things—they give us light and heat. It is by means of the sunbeams alone that we see anything. When the room was dark, you could not distinguish the table, the chairs, or even the walls of the room. Why? Because no light-waves came from them to your eye.

2. But as the sunbeams began to pour in at the window, the waves of light reached the things in the room. When they struck them they bounded from them to your eye, as a ball might bound back from the side of a house. Then, when they fell upon your eye, they entered it, and excited the retina and the nerves of sight, and the image of the chair or the table was carried to your brain.

3. Look around at all the things in the schoolroom. Is it not strange to think that each one of them is sending these unseen rays straight to your eye, as you look at each one? You see them, and distinguish them from one another, entirely by the kind of waves which they send to your eye.

4. Some substances send back hardly any waves of light, but let most of them pass through. A pane of clear glass, in a window, lets nearly all the light-waves pass through it. Often you cannot see that the glass is before you, because no waves of light come back to you from the glass. Those substances which, for some reason unknown to us, allow the waves of light to pass through them, are said to be *transparent.*

5. In clear glass, for example, nearly all the light-waves pass through the glass. In the case of a white wall, the greater part of the rays are sent back to your eye. Into polished, shining metal, the waves hardly enter at all, but are thrown back from the surface.

For this reason, a steel knife or a silver spoon are very bright, and can be clearly seen.

6. Quicksilver is put on the back of the glass in mirrors because it reflects so many of the waves of light. It not only sends back those which come from the sun, but those, too, which come from your face. So, when you see yourself in a mirror, the sun-waves have first touched your face and bounded from it to the mirror. Then, when they struck the mirror, they were thrown back, on to the retina of your eye, and you see your own face by means of the very waves thrown off from it an instant before.

7. But the light-waves do more for us than this. They not only make us see things, but they make us see them in different colors. What, you will ask, is this, too, the work of the sunbeams? Certainly, for the color we see depends on the size of the waves which come back to us from objects of different colors.

8. Imagine a sunbeam playing on a leaf. Part of the waves of light bound back from the leaf, straight to our eye, and make us see the surface of the leaf. The others go right into the leaf itself. The red, orange, yellow, blue, and violet waves are all useful to the leaf, and it does not throw those waves off. But it cannot take in the green waves, and so it throws them off. They come to your eye, and make you see a green color.

9. So, when you say a leaf is green, you really mean that the leaf does not want the green waves of the sunbeam, but sends them to your eye. In the same way, the scarlet geranium throws off the red waves. A white table-cloth sends back nearly all of the waves of light, and a black coat scarcely any. This is why, when there is very little light in the room, you can see a white table-cloth while you cannot see a black object. The few faint rays that are in the room are all sent back to you from a white object, but a black one sends no rays to your eye.

10. Is it not curious to think that there is really no such thing as color *in* the leaf, the coat, or the geranium flower? We see the different colors because, for some reason which we do not know, these objects send back to our eye only waves of a certain color.

Wherever you look, then, and whatever you see, remember that all the beautiful tints, colors, lights, and shades around you are the work of the tiny sunbeams.

11. Light does a great deal of work when it falls upon plants. Those rays of light which are caught and held by the leaf are by no means idle. We all know that a plant needs the sunlight, and becomes pale and sickly without it. The reason is, that, without these light-waves, the plant cannot get food out of the air, nor make the sap and juices which it needs.

12. When you look at the green grass on the lawn, at the beautiful flowers and plants in the garden, at the trees growing on the hillside, at the fields of waving grain, or at the lovely landscape, you are looking upon the work of the tiny sunbeams. These sunbeams never rest through all the long hours of the day, for they must help to give life to every green thing that grows on the earth.

1. What two things do the sunbeams do for us?
2. Why do we not see objects in the dark?
3. Why do we see them in the light?
4. How do we distinguish different objects from one another?
5. What are substances that allow light to pass through them called?
6. Why is a silver spoon bright?
7. What is put on the back of the glass in mirrors?
8. Explain how you see yourself in a mirror.
9. What does the color we see depend on?
10. What do you really mean when you say a leaf is green?
11. Why does a plant need the sunlight?

LESSON VI.

THE WORK OF THE SUNBEAMS.

II.

1. So far, we have spoken only of the waves of light, and some of the work that these waves do.

But there are other waves in a sunbeam. If you hold your hand in the sun, you can feel the heat of its rays. There are many waves in a sunbeam which move too slowly to make us see light when they touch the eye. But we can feel them as heat, though we cannot see them as light.

2. If you hold a warm iron near your face, you feel the waves of heat. You know that no light comes from the iron, yet you can feel the heat-waves beating rapidly against your face, and scorching it. Now, there are many of these dark heat-waves in a sunbeam, and it is these which do most of the work in the world.

3. In the first place, as they come quivering to the earth, they shake the water-drops apart, so that they can rise up into the air, as we shall see by and by. It is these drops, falling again as rain, which make the rivers, and all the moving water on the earth. The heat-waves, also, make the air hot and light, and cause it to rise, and thus winds are formed.

4. These dark waves strike upon the land, and give it the warmth without which plants could not grow. It is they, also, which supply the heat that keeps up the warmth in our bodies. They do this in two ways —by coming directly to us from the sun, and, also, in a very roundabout way, through those plants which we use as food.

5. Plants use up rays of light and heat in growing. Some of these plants we eat. Others are eaten by animals, and we eat the flesh of the animals. When we digest our food, that heat is set free in our bodies which the plants first took from the sunbeams. The heat you now feel in your body was once in a sunbeam.

6. There is yet another way in which the heat of the sunbeams comes to us through the plants. We burn wood and coal to cook our food, and warm our rooms. A little while ago the wood was part of a tree growing in the forest. But what is the coal? Long ages ago that was part of a tree growing in one of the vast forests which afterwards became the beds of coal deep down in the earth.

7. The heat the wood and coal give out when they are burned, is the heat they took in from the sunbeams while they were growing plants. Think how much work is done by this heat. Our houses are warmed by wood or coal fires. Our streets are lighted by gas made from coal. Our steam-engines and machinery are driven by water which has been turned into steam by the heat of burning wood or coal. Our steamboats travel all over the ocean by means of the same power.

8. The oil in our lamps comes from the remains of plants and animals in the earth. Our tallow candles

are made of the fat of animals that live on grass. Turn which way we will, we find that the light and heat on our earth, whether coming from fires, or candles, or lamps, or gas; whether moving the machinery of a mill, or driving a railway train, or propelling a steamship, are equally the work of the little waves of ether coming from the sun, which make what we call a sunbeam.

9. There are still other waves in a sunbeam, which are not useful to us as light or heat, and yet they are not idle. It is these waves which give us all our beautiful photographs.

And now, may we not say that the invisible waves which make our sunbeams are wonderful fairy messengers? From the creation of the world, they have been coming across space, never resting, never tiring, but always busy in doing the work of our world.

10. The ancient Greeks worshiped the sun. They put to death one of their greatest philosophers because he denied that the sun was a god. But we, who know more of nature and the God of nature than the wisest of the old Greeks, know that it is a huge globe made of burning gases and fiery matter, and not a god.

11. Surely we shall look at the sun with new interest, now that we can picture its tiny messengers, the sunbeams, flitting through all space. They fall upon

our earth, giving us light to see with, and beautiful colors to enjoy. They warm the air and the earth, they make the refreshing rain,—in a word, they fill this world of ours with life and beauty.

1. What do the sunbeams give us beside light?
2. What does most of the work of the world?
3. In what three ways do the sunbeams supply heat for our bodies?
4. What is the source of the heat in wood and coal?
5. What is the source of all the light and heat on the earth?
6. What is the sun?

LESSON VII.

NATURE AND SCIENCE.

I.

1. All the time that we are awake we are learning, by means of our *senses*, something about the world in which we live, and of which we form a part. We are constantly aware of feeling, or hearing, or smelling, and, unless we happen to be in the dark, of seeing. Now and then we taste. We call the impression made on the mind in this way, a *sensation*.

2. When we have any of these sensations, we commonly say that we feel, or hear, or smell, or see, or taste something. A certain scent, for instance, makes

us say we smell camphor; a certain flavor, that we taste peaches. A certain sound reaches our ear, and we say that we hear a carriage. A certain appearance before our eyes makes us say that we see a tree. We call that which we thus perceive by the aid of our senses a *thing*, or an *object*.

3. We say of all these things or objects, that they are the *causes* of the sensations produced, and that the sensations are the *effects* produced by these causes. For example, if we hear a certain sound, we say it is caused by a carriage going along the road, or that it is the effect of a carriage passing along. If there is a strong smell of burning, we believe it to be the effect of something on fire, and look about for the cause of the smell. If we see a tree, we believe that there is before our eyes a thing, or object, which is the cause of that appearance.

4. In the case of the smell of burning, when we find that something is on fire, we say that we know the *reason why* we perceive that smell, or that we have found the cause of the smell. So that to know the reason why of anything is to know the cause of it. But that which is the cause of one thing may be the effect of another.

5. Thus, suppose we find some burning straw to be the cause of the smell we perceive. We immediately ask, What set it on fire? Perhaps we find that a

lighted match had been thrown into the straw. Then we say the lighted match was the cause of the fire. But a match would not be in that place unless some person had put it there. Here is an effect produced by somebody as cause.

6. So we ask, Why did any one put the match there? Was it done carelessly, or did the person who put it there intend to do so? If so, what was his motive, or the cause that led him to do such a thing? What was the reason for his having such a motive? It is plain there is no end to the questions, one arising out of another, that might be asked in this way.

7. Thus we believe that everything is the effect of something which preceded it as its cause. This cause is the effect of something else, and so on, through a chain of causes and effects which goes back as far as we choose to follow it. Anything is said to be explained as soon as we have found the cause of it, or the reason why it exists.

8. The explanation is fuller, if we can find out the cause of that cause. The farther we can trace the chain of causes and effects, the more complete is the explanation. But no explanation of anything can be really complete, because human knowledge, at its best, goes but a very little way back towards the beginning of things.

9. When a thing is found always to cause a *certain* effect, we call that effect sometimes a *property*, sometimes a *power* of the thing. The odor of camphor is said to be a property of camphor, because camphor always causes that particular sensation of smell when it is brought near the nose.

10. Lead is said to have the property of heaviness, or weight, because it always causes us to have the feeling of weight when we handle it. A stream is said to have the power to turn a water-wheel, because it causes the water-wheel to turn. Properties and powers of objects, then, are certain effects caused by the things which are said to possess them.

1. How do we learn about the world in which we live?
2. What is a sensation?
3. What is an object?
4. What is it to know the cause of anything?
5. When is anything said to be explained?
6. Why can no explanation of anything be complete?
7. What is meant by a property of an object?
8. What other word is sometimes used to express this?

LESSON VIII.

NATURE AND SCIENCE.

II.

1. Many of the things brought to our knowledge by our senses, such as houses and furniture, carriages and machines, are termed *artificial things* or *objects*, because they have been shaped by the *art* of man. Indeed, they are generally said to be made by man.

2. A far greater number of things owe nothing to the hand of man. They would be just what they are, if man did not exist. The sky and the clouds, the sun, moon, and stars; the sea, the land, all wild plants and animals are things of this kind. Such things are termed *natural objects*. To the whole of them we give the name of *Nature*.

3. This distinction between nature and art, between natural and artificial things, is very easily made. Yet it is needful to remember that we owe everything to nature. Those artificial objects which we commonly say are made by men, are only natural objects shaped and moved by men. In the sense of *creating*, that is to say, of causing something to exist which did not exist in some shape before, man can make nothing whatever.

4. We talk of "making" a box. We mean, only,

that we have shaped the pieces of wood and nailed them together. The wood is a natural object, and so is the iron of the nails. A watch is "made" of the natural objects gold and other metals, brought together and shaped in various ways. A coat is "made" of the natural object wool; a dress, of the natural objects cotton or silk. The men who make all these things are themselves natural objects.

5. Carpenters, jewelers, tailors, shoemakers, and all other artisans, are persons who have learned so much of the powers and properties of certain natural objects, and of the chain of causes and effects in nature, that they are able to shape and put together natural objects in such a way as to make them useful to man. A carpenter could not, as we say, "make" a box, unless he knew something of the properties and powers of wood. The practice of every art requires some knowledge of natural causes and effects.

6. Among natural objects, as we have seen, there are some that man can get hold of and turn to his own use. But all the greatest things in nature, and the links of cause and effect which connect them, are entirely beyond our reach. The sun rises and sets; the moon and stars move through the sky; fine weather and storms, cold and heat, follow each other in turn.

7. Cyclones ravage one spot; earthquakes destroy

another; volcanic eruptions lay waste still another. A fine season brings health and plenty here; a long drought spreads disease and famine there. In all such cases, the direct influence of man can effect nothing. So long as he is ignorant of their cause, man is the mere sport of the greater powers of nature.

8. The first thing that men learned, as soon as they began to study nature carefully, was that some events take place in regular order, and that some causes always produce the same effects. The sun rises and sets day after day. The seasons follow one another in the same order. Plants grow up from seed. They yield seed from which like plants grow up again. Animals are born, grow, reach maturity, and die, age after age, in the same way.

9. In this way the notion of an *order of nature*, and a fixed relation of cause and effect between things, slowly entered the minds of men. So far as such an order could be seen, it was felt that things were explained by it. The things that could not thus be explained were said to have come about by *chance*, or to have happened by *accident*.

10. But the more carefully nature has been studied, the more widely has order been found to prevail. What seemed to be disorder, has proved to be nothing but order not understood. No one is so foolish now, as to believe that anything happens by chance, or

that there are any accidents, in the sense of events which have no cause. If we say that a thing happens by chance, every one knows we really mean that we do not know its cause, or the reason why that particular thing happens. Chance and accident are only other names for our own ignorance.

11. It may be that a man seeks shelter under a tree during a heavy storm. Perhaps, if a stronger gust than usual comes, a branch may break, fall upon the man, and seriously hurt him. If that happens, it will be called an accident. The man will perhaps say that by "chance" he took refuge under the tree, and so the "accident" happened. But there is neither chance nor accident in the matter.

12. The storm is the effect of causes acting upon the atmosphere, perhaps hundreds of miles away. Every motion of a leaf is the effect of the force of the wind acting on the surface of the leaf. If the branch breaks, it will do so because of the difference between its strength and the force of the wind. If it falls upon the man, it will do so because of the action of other natural causes.

13. The position of the man under the branch is the last one of a series of causes and effects. These have followed one another in regular order, from the cause of his leaving home to that cause the effect of which made him take refuge under the tree. But, as

we are not wise enough to trace out the long series of causes and effects that led to the falling of the branch upon the man, we call such an event an accident.

1. What are artificial objects? natural objects?
2. To what do we give the name of Nature?
3. What are the natural objects of which a box is made?
4. What kind of objects are the nails in a box?
5. What does the practice of every art require?
6. What was the first thing men learned when they began to study nature carefully?
7. What do we really mean by chance or accident?

LESSON IX.

NATURE AND SCIENCE.

III.

1. When we have found by careful and repeated observation that certain events always take place in the same order, or that something is always the cause of a certain effect, we speak of the truth thus discovered as a *law of nature.* Thus, it is a law of nature that anything heavy falls to the ground if it is not supported. It is a law of nature that lead is soft and heavy, while glass is hard and brittle.

2. Experience shows us that heavy things always do fall if they are not supported, and that, under

ordinary conditions, lead is always soft, and glass is always hard. But we must remember this fact, which is very often lost sight of. The laws of nature are not the causes of the order of nature. They are only a way of stating what man has learned of the order of nature.

3. Stones do not fall to the ground in consequence of the law of nature just stated, as people sometimes carelessly say. The law is a statement of what always happens when heavy bodies at the surface of the earth, stones among the rest, are free to move. The laws of nature are, in this respect, like the laws which men make to regulate their conduct towards one another.

4. There are laws about the payment of taxes, and there are laws against stealing and murder. But the law is not the cause of a man's paying his taxes, nor is it the reason why men do not steal or commit murder. The law is simply a statement of what will happen to a man if he does not pay his taxes, or if he commits theft or murder. So a law of nature tells us what we may expect natural objects will do under certain conditions.

5. Let us remember this,—nothing happens by chance, but everything in nature follows a fixed order. The laws of nature state in accurate language that which men have been able to learn about the order of

nature. It follows, then, that it is very important for us to know as many as we can of these laws of nature, so that we may guide our conduct by them.

6. If a man should try to live in a country without knowing anything about the laws of that country, or without paying any attention to them, he would probably soon find himself in trouble. If he should be fined, or put in prison, people would very likely say that he had deserved such treatment by his own folly.

7. In like manner, any one who tries to live upon this earth without attention to the laws of nature, will live here but a very short time. In fact, nobody could live for half a day, unless he attended to some of the laws of nature. Thousands are dying daily, thousands more are living in misery or great discomfort because men have not yet learned as much as they might know of the laws of nature.

8. Men cannot alter the seasons, or change the process of growth in plants. But they can learn the order of nature in these matters, and make their plans for sowing and reaping at the proper time. They cannot make the wind blow. But when it does blow, they can make use of it to sail ships and turn windmills. They cannot control the lightning, but they can make it harmless by means of lightning-rods. They did not know how to do these things until they had learned some of the laws of nature.

9. Perhaps you have thought of science only as a collection of dry facts in some dull book. No one can like dry facts, or dull books; no one need try to like them. Nature does not give dry facts to every one. She never gives them to those who ask her, in a loving, earnest spirit for something else. Facts, as mere facts, are dry and barren, but nature is full of life and interest.

10. All accurate knowledge is *Science*. The method by which the great results of science have been obtained is just the same as that which is used by every one, every day of his life. If a child is given a new toy, he observes its nature and experiments upon its properties. We are all of us constantly making observations and experiments upon one thing and another.

11. The scientific method of observation and experiment is the same as the common method, only it tries to be accurate. Common knowledge grows into scientific knowledge as it becomes more and more exact and complete. The way to science, then, lies through common knowledge. We must increase that knowledge by careful observation and experiment. We must learn how to state accurately what we thus find out. In this way we shall acquire a knowledge of nature that will serve to guide us in all the paths of our daily life.

1. What is a law of nature?

2. What do the laws of nature state?

3. Why is it important for us to know as many as we can of these laws?

4. What is science?

5. How does common knowledge grow into scientific knowledge?

6. How can we increase our store of common knowledge?

LESSON X.

WATER.

1. One of the most common of natural objects is water. Everybody uses it in one way or another: everybody has a store of common knowledge about it. But few people, however, have given careful attention to what they already know about this object. Those who have never tried to learn that which may be learned about water, do not know many of its powers and properties, or the laws of nature which it illustrates.

2. Suppose we have a tumbler half-full of water. The tumbler is an artificial object. Certain natural objects have been brought together and heated until they melted into glass. This glass has been shaped by some workman into a tumbler. The water, on the

other hand, is a natural object. It has come from some river, pond, spring, or well.

3. Water has a great number of peculiarities. It is transparent,—that is, it lets nearly all the waves of light pass through it, and so you can see through it. It feels cool; it will quench thirst, and dissolve sugar or salt. But these are not the peculiarities of water it is best for us to notice at first.

4. The water fills the tumbler for half its height. It occupies that much space, or, as we say, has that *volume.* When the space occupied by any object is measured, we call the amount of space the volume of the object. A block of wood, for instance, is six inches long, four inches wide, and three inches thick. It occupies seventy-two cubic inches of space; therefore we say its volume is seventy-two cubic inches. We might measure the water in the tumbler, and express its volume in cubic inches.

5. If you put the closed end of a tumbler into one nearly filled with water, you will find, when the water is reached, that it will hinder the tumbler from going down. Unless some of the water can get out, the end of the second tumbler will not go any farther. If you strike your open hand on any surface of water, you will receive a shock when the hand touches the water. This is owing to what is called the *resistance* of the water.

6. If the water in the tumbler is poured out, the tumbler feels lighter than it did before. Water, therefore, has *weight.* If you throw the water out of the tumbler, at any object that is only slightly supported, the water striking against the object will push it over. That is to say, if water is put in motion it is able to transfer its motion to something else.

7. All these things we have noticed are effects of which water is the cause. They are, therefore, properties of water. All things which occupy space, offer resistance, possess weight, and transfer motion to other things when they strike against them, are termed *material substances* or *bodies,* or simply *matter.* Water, therefore, is a kind of matter.

8. You will easily notice that, although water occupies space, it has no definite shape. It always fits itself exactly to the shape of the vessel that holds it. The tumbler is round, and hence the edge, or side, of the water is round, or circular. Whatever the shape of the vessel into which you pour water, the sides of the water always fit exactly against the sides of the vessel.

9. If you put your finger in the water you can move the finger in all directions with hardly any feeling of hindrance. When you take your finger out there is no hole left. The water from all sides rushes in to fill up the space that was occupied by the finger. You

cannot take up a handful of water, for it runs away between your fingers.

All this shows that the particles of water move upon one another with great ease.

10. But although the particles of water thus loosely slip and slide about upon one another, they hold together to a certain extent. If the surface of the water in the tumbler is just touched with the tip of the finger, a little of the water will adhere. If the finger is slowly raised, the water will form itself into a drop. Have you not sometimes seen in the early morning, on the blades of grass, little drops of dew, the particles of which held themselves together in this way?

11. Material substances, the particles of which move so easily that they fit themselves exactly to the sides of any vessel which contains them, are called *fluids* Fluid bodies are of three kinds, but at present we have to do with only one kind. Fluids, the particles of which do not fly off from one another, but hold together as those of water do, are called *liquids*.

Water, therefore, is a liquid.

1. What kind of an object is a tumbler?
2. What kind of an object is water?
3. What is meant by the volume of a body?
4. Name the first property of water mentioned in the lesson.
5. Name the second; the third; the fourth.
6. What are fluids? liquids?
7. What is water?

LESSON XI.

THE MEANING OF WEIGHT.

1. We say that anything has weight, if we find, on trying to lift it from the ground, or on holding it in the hand, that we must make an effort. If we lift it, or hold it in the hand, we have a feeling of effort. If anything which is supported a little distance above the ground falls, when the support is taken away, we say it has weight.

2. Now the ground is the surface of the earth. All bodies which have weight, fall directly towards the surface of the earth when they are not kept away from it, and prevented from doing so, by some means. We may therefore say that all bodies which have weight tend to fall in this way.

3. It does not matter upon what part of the surface of the earth you make an experiment to test this. Rain consists of drops of water. If we watch a shower of rain in calm weather, we see that the drops fall in a straight line towards the ground. We know that the earth is a globe. If two showers are falling at the same time, one here, in our part of the earth, and one on the other side of the globe, directly opposite to us, the drops must be falling in opposite directions, and towards one another.

4. The drops of both showers are, in fact, falling, in a straight line, towards the center of the earth. You will easily understand how this is, if you look at a school globe and imagine the rain-drops falling, at the same time, upon any two points on the globe that are directly opposite each other.

5. All bodies which have weight tend to fall towards the center of the earth. That is to say, they will fall in that direction if there is nothing to prevent them. When we speak of weight, we really mean this tendency to fall towards the center of the earth. To call anything heavy is the same as saying that, if there is nothing to support it, it will fall to the ground, or that, if we support it ourselves, we shall have to make an effort in order to do so.

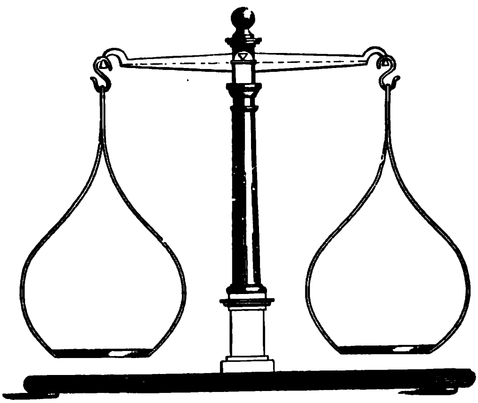
6. We say that a tumbler full of water is heavier than an empty tumbler. The full tumbler causes a greater feeling of effort, when we lift it, than the empty tumbler does. A pail full of water requires a still greater effort, though the empty pail is not heavy. If we try to lift a large tub full of water, we may be unable to move it, though we could lift the empty tub with ease.

7. It seems, then, that the more water there is, the more it weighs, and the less there is, the less it weighs. In other words, the greater the volume of water, the greater the weight. But a single drop of water on

the hand seems to weigh nothing at all. We are not conscious of any effort in supporting it. A moment's thought, however, will show us that it must have weight, for the drop readily falls to the ground.

8. Besides, a few thousand drops will fill a tumbler. If a thousand drops weigh something, each drop must weigh the thousandth part of that weight. The fact is, our feeling of effort is a very loose measure of weight. We cannot compare small weights by means of it, nor, indeed, can we perceive them if they are very small.

9. To know anything accurately about the weight of bodies, we must make use of an instrument which is made for the purpose of measuring weight correctly. Such an instrument is called the *balance.* You may see one in any drug-store. Here is an illustration of the balance.



10. It has a beam which moves easily on a pivot fixed to the standard in the center. From each end of the beam a scale-pan is hung. So long as both pans

are empty, the beam remains level, as you see it in the picture. This is because one pan has just as strong a tendency to fall towards the center of the earth as the other, but one cannot go down without pulling the other up. The pans, therefore, balance each other.

11. If you put anything that has weight into one pan, that pan goes down, and the other rises. Little pieces of iron or brass, called *weights*, the weight of which has been carefully measured, are put in the empty pan until the beam comes back to a level position. The weights then show how much the object in the other pan weighs. The balance is sometimes made so carefully that it will weigh the thousandth part of a grain. By means of it, a drop of water can easily be weighed.

1. When do we say that anything has weight?
2. In what direction do all bodies that have weight fall, when not supported?
3. What do we really mean when we speak of weight?
4. What is meant by calling anything heavy?
5. What is the balance used for?
6. Describe the balance.

LESSON XII.

THE CAUSE OF WEIGHT.

1. We really know nothing at all of the reason why bodies have weight. There is, however, a law of nature which tells us *how* bodies tend to fall towards the center of the earth, but not *why* they do so. This law, which is called the *law of gravitation*, was discovered by Sir Isaac Newton.

2. Many careful observations and experiments have shown it to be a law of nature that every material substance tends to approach every other material substance, just in the same way as a drop of rain falls to the earth. Any two portions of matter anywhere in the universe will move towards each other if there is nothing to hinder them from doing so. What is called the law of gravitation is only a statement of this fact in full and accurate language.

3. To make this clear, let us suppose that there are only two material bodies in the universe, and that these bodies are two little drops of water, of the same size. Each of these drops would have the same volume as the other. Then, however far apart the two drops were, they would begin to move towards each other. Moving faster and faster as they went along, they

would at length meet at a point just half-way from where each drop started.

4. But suppose that one drop were larger than the other. In that case the larger drop would move more slowly than the other, and the point of meeting would be nearer the larger drop. If the larger drop were twice the size of the smaller drop, the larger one would travel only half as far as the smaller one.

5. If one drop were as large as our earth, and the other only the size of a rain-drop, what would happen? The larger drop would still move towards the little one. But the space the larger drop would move over would be such a minute part of the whole distance between the two drops, that it would not seem to move at all. It would appear as if the large drop were perfectly still, and drew the small drop to itself.

6. Now this is just what happens when a single drop of rain falls from the clouds to the earth. The earth really moves towards the drop, just as the drop moves towards the earth. But the distance each moves over depends upon the quantity of matter which each contains. The earth moves such a very small part of the distance, that we cannot measure it, or, indeed, form any idea of it. So we say the drop falls to the earth, and do not speak about the earth's moving towards the drop.

7. What is true, in this case, of the earth and a rain

drop, is true, so far as we know, of every kind of matter. "Every particle of matter in the universe has an attraction for every other particle,"—that is to say, they all tend to move towards one another. This is what is meant by *gravitation.* The attraction between the earth and bodies on or near its surface, is called *gravity.*

8. It is often said that gravity is attraction, and that bodies fall to the earth because the earth attracts them. But the word "attract" only means "to draw towards." To say, when two bodies move towards each other, that they are drawn towards each other, only describes the fact. It does not explain it, or tell us any more about the cause of it than we knew before.

9. Again, gravity is spoken of as a *force.* As the word "force" is in very common use, let us try to find out what it means. A man is said to exert force when he pushes or pulls anything so as to put it in motion. When we throw a ball, the force put forth is shown by the swiftness of the motion of the ball.

10. Force is the name we give to that which causes motion, or tends to cause it. The force of gravity, then, is the cause of the movement of bodies towards the center of the earth, when they are free to move. Or, it is the cause of the feeling of effort which we have when we try to support them, and keep them from falling to the ground. But we know nothing at

all about the cause of their falling to the ground, or the reason why they do so.,

11. A great deal of harm is done by the wrong use of such words as "force" and "attraction." They are often used as if they were the names of things that really exist. In reality they are only names for the unknown cause of certain effects which we see. It is well for us to take pains to get a clear idea of this.

12. Let us sum up what has been said about the cause of weight. So far as we know, it is a law of nature that any two bodies, left free to move, will approach each other. The space over which each will move before they meet, depends on the quantity of matter which each contains. This law is called the law of gravitation.

13. Gravitation is a name for this general fact. Gravity is the name for this fact in the case of bodies on the earth, and weight is the measure of gravity. Force is the name which we give to the cause of the fact. We know nothing whatever about this cause. The fact we know; and that is what it is important for us to know. The names are of no great consequence, so long as we remember that they are only names, and not things.

1. What do we know of the cause of weight?

2. How has it been shown that all bodies tend to approach one another?

3. What really happens when a drop of rain falls to the earth?
4. What does "attract" mean?
5. To what do we give the name of "force"?
6. If any two bodies are left free to move, what will happen?
7. What does the space over which each will move depend upon?

LESSON XIII.

THE MEANING OF "HEAVY" AND "LIGHT."

1. We are in the habit of using the words "heavy" and "light" rather carelessly. In fact, you must now see that, in common language, we use many words without a due regard to their precise meaning. We call things that are easy to lift, *light*; and things that are hard to lift, *heavy*. We say that a piece of iron is heavy, while we say of a piece of wood of the same size, that it is light.

2. Yet the block of wood may be larger than the piece of iron. A block of wood which weighs a pound is much larger than a piece of iron of the same weight. In order to avoid the confusion which grows out of this difference in the size and weight of bodies, we need a standard with which to compare the weight of different substances.

3. Water is taken for such a standard. It is so common we can easily compare the weight of any sub-

stance with the weight of the same quantity of water. The weight of a given volume of any substance, as compared with the weight of the same volume of water, is called its *specific gravity.* For instance, a cubic foot of water weighs nearly sixty-two and a half pounds. A cubic foot of cork weighs only fifteen pounds. Cork is, therefore, not quite one-fourth as heavy, volume for volume, as water.

4. A cubic foot of dry white pine wood weighs twenty-five pounds. That kind of pine wood is, therefore, not quite half as heavy as water. A cubic foot of common brick weighs one hundred and twenty-five pounds. Brick is, therefore, twice as heavy as water. A cubic foot of cast iron weighs four hundred and forty-seven pounds. Therefore iron is about seven times as heavy as water.

5. Now, since the weight of any substance, as compared with the weight of the same volume of water, is called its specific gravity, we say that the specific gravity of cork or pine is less than that of water; and that the specific gravity of brick or iron is greater than that of water. In this sense, that is to say, as compared with water, cork and pine are light, while brick and iron are heavy.

6. If you take two tumblers of water and throw some sand into one, and some sawdust into the other, what will happen? The sand will sink to the bottom

of the tumbler; the sawdust will float at the top of the water. You may stir them up as much as you like, but the sand will fall to the bottom, and the sawdust will rise to the top. Why is this? The sand is heavier than water; the sawdust is lighter. That which is heavier than water, volume for volume, will sink in water; and that which is lighter, will float.

7. Drop a small piece of the thin, tinned sheet-iron, commonly called "tin," into the water. What happens? The tin is heavier than water, and therefore it sinks. But drop a small tin box into the water. The box does not sink at all. It floats on the water as if it were made of cork. Yet the box is made of tin, which is heavier than water, and we have just seen that tin will sink in water.

8. We were sure just now that tin is heavier than water, and yet here is a tin box floating in the water. Were we wrong? Is a tin box an exception to the law of nature, that what is heavier than water sinks, and that which is lighter, floats? Not at all. What we said was,—that which is heavier than water, *volume for volume*, will sink.

9. Now the question arises, Is the tin box as heavy as a volume of water of the same size? How can we find out? Very easily, as we shall see. With the balance we can soon find how much the box weighs.

Let us next try to find how much the same volume of water weighs. As the sides of the box are very thin, the inside of the box is almost as large as the whole box.

10. If we fill the box with water, and then weigh the water, we shall find out, very nearly, what is the weight of a volume of water of the size of the box. But if we do this, we shall find that the water in the box weighs much more than the box does. So that, volume for volume, the box, although it is made of tin, is really lighter than water. That is the reason why it floats.

11. You have heard of iron ships. Perhaps you have wondered how it is that ships made of thick, heavy plates of iron, and weighing many thousand tons, do not sink to the bottom of the sea. But iron ships are like our tin box in this respect. They float because each ship weighs less than a quantity of water of the same volume does.

12. It is because of this property of water—that it will bear up things lighter than itself—and also because of that other property of water which we have seen—that its particles move easily upon one another—that the sea, and lakes, and rivers, and canals are so useful to man. He is able to make highways of them upon which people can travel about the country, or to different parts of the world.

13. Ships loaded with hundreds of tons of freight, float because the weight of the ship and its load is less than the weight of the same volume of water. The particles of water are so easily moved, that the force of the wind, or the paddles of a wheel can readily cause a ship to move through the water.

1. What things do we call "light"?
2. What things do we call "heavy"?
3. What is taken as the standard with which to compare the weight of different substances?
4. What do we really mean when we say that cork is light, and iron is heavy?
5. Why does a tin box float in water?
6. Why do iron ships float?
7. How does man make use of the fact that water will bear up things lighter than itself?

LESSON XIV.

THE PRESSURE OF WATER.

1. If you press down upon the tin box, as it floats in the water, there is a feeling of resistance as the box sinks. When the pressure is taken off, the box at once rises to the surface. This is because the water presses upwards against the bottom of the box. It also presses against the sides. If the sides of the box are very thin, they may be forced in by the pressure

of the water. If a thin, empty glass bottle is tightly corked and lowered into deep water, the cork will be driven in, or else the bottle will be crushed.

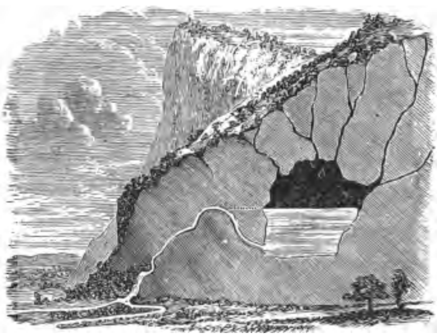
2. Water presses in all directions upon things which are sunk in it. It will also transmit pressure in every direction—upward, downward, and on every side—at the same time. An experiment tried by Pascal, a famous French philosopher, who was born in 1623, is shown in the illustration. He fixed a narrow tube, about thirty feet high, into the head of a cask, and then filled the cask and the tube with water. The pressure of the water in the tube burst the cask.

3. If you notice the water in a tea-kettle, you will see that the water always stands at the same level in the kettle, and in the spout. If a glass tube is bent into the shape of a U, and water is poured into it, the water will always stand at the same level in the two legs of the tube, whatever the shape of the bend, or the size of the legs of the tube may be.

4. In cities water is supplied to the houses. It is

often drawn from faucets in the highest stories of tall buildings. These are fed by pipes which come from a large pipe, or *main*, in the street. If you followed the main you would find that it took a long course under the pavement of the streets until, at last, it reached the water-works.

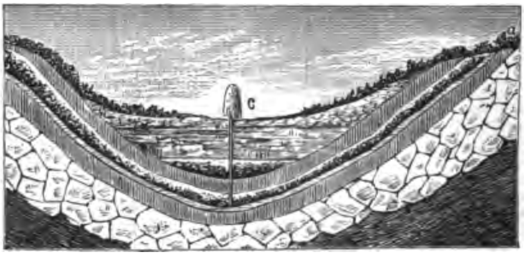
5. Here you could see that the main is connected with a reservoir, which is higher than any point where the water is delivered. Thus the reservoir, the main, and the house-pipe form one great U-tube. The water in the house-pipe tends to rise to the same level as that in the reservoir. Hence, when the faucet of the house-pipe is turned, the water flows freely from the pipe.



6. Some kinds of springs flow in the same way. Here is a representation of such a spring. There is a reservoir deep in the rock, which is filled by water trickling into it through cracks in the rock. When this reservoir is filled to the level of the highest point in the spout-like channel which forms the outlet, the water begins to flow, and comes out at the surface of the ground in a spring. These are

called *intermittent springs*, because they flow for a time, and then stop flowing for a time. They cease to flow when the water in the reservoir sinks below the highest point of the channel leading from the reservoir.

7. In some parts of the country deep wells, called *artesian wells*, are bored to obtain a supply of water. Sometimes they are many hundred feet deep. These, too, are like the U-tube. Such a well is represented in the illustration.

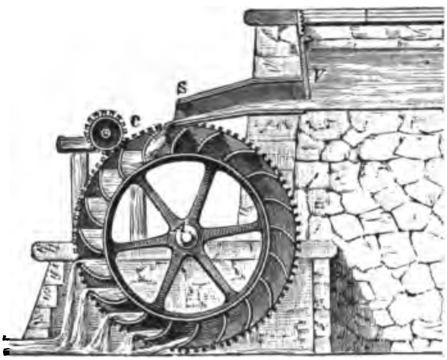


A hole is bored into the earth until a layer of water is reached which is fed from some source higher than the outlet of the well. Then the water flows out at the surface of the ground, sometimes rising high into the air. The hills on either side of the valley in which the well is, may be hundreds of miles apart.

8. One of the properties of water spoken of in a previous lesson is its power to transfer motion. Man turns this property of water to his own use by making running water do some of the work he is not strong

enough to do. But water cannot put itself in motion. It must be put in motion by some force. A running stream is water falling down hill. It is put in motion, and kept in motion, by the force of gravity.

9. In all kinds of water-mills the motion of water, falling more or less rapidly, is turned to account. Here is an illustration of a water-wheel. The water is made to flow against buckets or floats on the rim of the wheel. It transfers some of its own motion to each bucket. The bucket moves away, and thus makes the wheel turn. The turning of the wheel brings another bucket into the falling stream.



10. This is moved in the same way, and the wheel turns still farther. Thus each bucket is a means by which some of the motion of the water is caught, as it were, and transferred to the wheel. The machinery of the mill is only a contrivance for transferring the motion of the wheel to the place where the work of the mill is to be done.

The illustration also shows how a wheel is some-

times made so that it can transfer the motion it has received from the water to the machinery of the mill.

11. But while this property of water is very useful to man when he can control and direct its operations, it is sometimes the cause of great harm. A mountain stream, suddenly swollen by rain or melting snow, may become a rushing torrent, tearing away great masses of rock, uprooting tall trees, pushing houses from their foundations, and sweeping everything before it. The quiet stream that had been a thing of beauty in the peaceful landscape has suddenly become a raging flood that is dangerous to the property and perhaps to the life of man.

1. How does water press upon things which are sunk in it?
2. In what direction does water transmit pressure?
3. Describe Pascal's experiment.
4. How is water supplied to the houses in a city?
5. What is an intermittent spring?
6. When do such springs flow? When do they cease to flow?
7. Describe an artesian well.
8. How does water turn a water-wheel?
9. How is the motion of a water-wheel transferred to the place where the work of a mill is done?

LESSON XV.

THE EFFECT OF HEAT ON WATER.

1. Water which has stood for some time in a warm room becomes smaller in volume, or *contracts*, if it is taken into a cool room. If water is heated, its volume increases, or it *expands*.

Hot water is lighter than cold water. This is easily seen when a bath-tub is filled from two pipes, one of hot, and one of cold water, which run at the same time. Unless care is taken to stir the water, the top of the water will be much hotter than the bottom.

2. Thus a change in the properties of water is made by heating it ever so little. If it is heated to a high degree, a still greater change takes place. You know what happens when a pan containing water is put on the stove. The water gets hotter and hotter. Then it begins to simmer, and finally it boils away into steam, which passes into the air and disappears.

3. If the boiling goes on long enough all the water will disappear. It looks, at first, as if the water had been destroyed by the heat. In reality, however, not a particle of water has been destroyed. It has only changed its form. The heat has changed it from the state of liquid water into that of *gaseous* water, which is called *vapor* or *steam*.

4. Try the same experiment with a tea-kettle, but put only a little water in the kettle, and shut the lid down. As soon as the water begins to boil, the steam will shoot out of the spout in a jet. This will go on as long as any water remains in the kettle.

5. The steam, as it comes out of the spout of the kettle, is so hot that it will scald you if you put your finger in it. If you look through the jet of steam, just as it leaves the spout, you will see that it is transparent. At some little distance from the spout the steam loses its transparency, changes into a white cloud, and soon disappears in the air.

6. If you put a cold spoon in the jet of steam for a moment, you will notice another change. When you take the spoon away, you will find that it is quite wet. The spoon has become hot, and is covered with drops of warm water. What has happened here?

7. The heat has passed from the fire to the tea-kettle, and then to the water which the kettle holds. The water has become hotter and hotter. When it had reached a certain degree of heat, it was changed into steam, or vapor of water. When the steam touched the cold spoon, it gave up to the spoon the heat it had taken in. It was this heat which kept the water in the state of a vapor, and when the heat was lost, the water passed back into the state of a liquid.

8. Thus steam and water are two forms or states of the same thing—water. The steam is the effect of the heat which the water has taken in.

If you could measure and weigh the water in the kettle to begin with, and then measure and weigh all the steam into which the heat of the fire changes the water, you would find that the volume of the steam was nearly seventeen hundred times greater than the volume of the water. But the weight of the steam would be exactly the same as the weight of the water.

9. The power with which water expands when it is changed into steam is very great. If you were to stop up the spout of the kettle, the steam inside the kettle, in trying to expand, would blow off the lid. If you were to fasten down the lid, the steam would soon burst the kettle itself. You sometimes hear of the strong boilers of steam-engines being burst in this way.

1. When does water contract?
2. When does it expand?
3. How does hot water compare in weight with cold water?
4. Into what state is liquid water changed by heat?
5. How much greater is the volume of steam than that of the water which is changed into steam?
6. When steam loses its heat what change takes place?

LESSON XVI.

THE EFFECT OF COLD ON WATER.

1. We have seen what a wonderful change is brought about by heating water. At first it expands a little, but very slowly. When it reaches the boiling point it suddenly expands to an enormous extent. It is now no longer a liquid, but has become a gas.

On the other hand, if warm water is allowed to cool, it slowly contracts until it becomes as cool as the surrounding air in mild weather. If the weather is very cold, it goes on contracting down to a certain point.

2. This point is the temperature of thirty-nine degrees above zero, as shown by the common thermometer. If cooled below this point, it begins to expand again. In this peculiarity water is unlike all other fluids. At the temperature of thirty-nine degrees above zero water is heavier, volume for volume, than the same water at any other temperature. For this reason the weight of pure water at this temperature is taken as the standard with which to compare the weight of other substances when we wish to find their specific gravity.

3. If we put a pail of water out of doors on a cold winter's night, we shall find it frozen solid in the

morning. Let us see how this change has come about. The water slowly cooled until that at the top of the pail reached the temperature of thirty-nine degrees. Then, being heavier than the water below it, it sank to the bottom of the pail, while the water at the bottom rose to the top. In this way, all the water in the pail cooled to the temperature of thirty-nine degrees.

4. As it cooled below this point, the colder water would accumulate at the surface because it was lighter than the rest. Its temperature would slowly fall to thirty-two degrees above zero, the point at which water begins to freeze. As soon as the upper water cooled ever so little below thirty-two degrees, a thin film, like glass, would form on its surface. The liquid water has been changed into solid water, or *ice*. As all the water in the pail cooled down to the same degree, it would all change into ice.

5. In this condition water is *solid*. We have now seen water in three different forms, or states. First, it was a liquid. Heat changed it into steam, and steam is a gas. Cold has now changed it into ice, which is a solid. The three different forms in which we have seen water are, then, the liquid, the gaseous, and the solid form.

6. The ice occupies space, offers resistance, has weight, and transmits motion, just as we have seen that water does. If you shake the ice out of the pail,

in a cold place, you will see that it keeps its form without the least change. In this respect it is unlike water or steam.

7. We know that any quantity of steam has exactly the same weight as the water which was changed into the steam by heat. So ice has the same weight as the water which was changed into it by cold. But the volume of steam, you remember, is nearly seventeen hundred times greater than that of water. The volume of ice is about one-eleventh greater than that of water.

8. Ice is, therefore, lighter than water. Hence, as you know, it floats in water. This property of ice is of great benefit to us. Were the ice heavier than water it would sink to the bottom. Then the water above it would freeze, until finally the water of our rivers and lakes would freeze into a solid mass. Everything living in the water would be frozen. More than that, if the water were very deep, the heat of summer could not melt all the ice that formed in winter. In countries where the streams froze in winter, they would remain frozen the entire year.

1. At what temperature does water begin to freeze?
2. What is ice?
3. In how many different forms is water found? What are they?
4. Why does ice float in water?

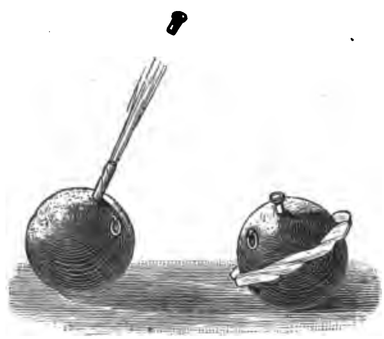
LESSON XVII.

THE POWER OF FREEZING WATER.

1. Although water in freezing expands only to the small extent of one-eleventh of its volume, it is like steam in the tremendous force with which it expands. You may have seen a pail or a pitcher that had been burst by the freezing of the water within them. You know that in winter, in severe weather, the pipes by which water is brought into a house sometimes burst.

2. This is because the water in the pipes freezes. In freezing it expands, and presses against the sides of the pipes with such force that it bursts the pipe.

One cold day in winter an army officer at Quebec tried the experiment which is shown in the illustration.



3. He filled an iron shell with water and closed the opening of the shell by driving in a wooden plug. The water froze, and the ice, in expanding, forced the plug about three hundred feet into the air. Some of the ice itself was forced out of

the opening, forming a plug of ice about eight inches long. In another shell filled with water, the opening was tightly closed. This shell was split, and a rim of ice forced through the crack.

4. The expansion of freezing water does a great deal of work that is useful to man, as we shall see by and by. Among the bare hill-tops, or on the face of cliffs exposed to the weather, the strongest and hardest rocks are every winter split and broken up, as if by the hand of man. In the summer the rain gets into the little cracks in the rock, and lodges there. When winter comes with its cold, the water freezes and bursts the rock asunder, just as it sometimes bursts the water-pipes in a house.

5. Ice, liquid water, and steam are three things as unlike as any three things can well be. What do we mean, then, by saying that they are different states of one substance—water?

What we really mean is that, if we take a given quantity of water, say a cubic inch, and change it first into ice, and then into steam, there is something which remains just the same through all these changes.

6. This something is, in the first place, the weight of the water. The cubic inch of water weighs two hundred fifty-two and a half grains—about half an ounce. The ice into which it is frozen, and the steam

produced from it weigh, each, the same number of grains.

In the second place, the same force would cause the ice, the water, and the steam to move with the same swiftness. When put in motion they would produce the same effect upon anything against which they struck.

7. In the third place, when you study chemistry, you will learn that the ice, the steam, and the liquid water will yield the same weight of the same two gases, *oxygen* and *hydrogen*, and nothing else. This shows us, beyond any question, that ice the solid, water the liquid, and steam the gas, are three states of one natural object. We have found out, by simple experiments, that the condition of each state is the presence of a certain amount of heat.

1. To what extent does water expand in freezing?

2. Why do water-pipes sometimes burst in severe weather?

3. Describe the army officer's experiment.

4. What happens when water freezes in the cracks in the rocks?

5. If enough heat is added to water, what change will take place?

6. If enough heat is taken from water, what will follow?

LESSON XVIII.

WHAT HAPPENS WHEN FIRE BURNS.

1. We have seen that there are many things to be learned about even so familiar and common an object as water. Fire is another common object. It may be seen every day of our lives. But what is it? The only way in which we can get an answer to this question is to ask Nature for it. In other words, we must make an experiment. If this is rightly made, we shall surely get the information we need.

2. What happens when a candle burns? The wax or tallow and the wick gradually disappear. At last the candle is gone—wax, wick and all. What has become of the candle? Has it been destroyed? Is it lost? So far as our eyes are concerned, it is lost; but the ship which sails away on the sea is also lost to our eyes. Yet we know that the ship still exists, though we do not see it. If we put a lump of sugar into a cup of tea, the sugar appears to be lost. Yet we know that the sugar is still there, because the tea is made sweet, and we can taste the sugar.

3. We must look for the wax of our candle by the help of a simple experiment. Let us light a candle and hold over it a clean glass bottle, putting the neck of the bottle well down over the flame. After the

candle has burned for a little while, we shall notice that the flame grows smaller and smaller. In a short time the candle goes out.

4. This is the first thing for us to observe. We must next find why the candle went out. For this purpose we must see if the air in the bottle is now the same as it was before the candle was burned. Let us pour some clear *lime-water* first into a bottle in which no candle has burned, and then into the one in which our candle burned and went out.

5. You see the difference at once! In the first bottle the lime-water remains clear. In the second, it becomes milky in appearance. Hence we see that the air in the bottle has been changed in some way by the burning of the candle. You can easily prepare some lime-water by letting a piece of fresh lime stand in water, shaking it up once in a while, and finally letting the water settle until it becomes clear.

6. The milky appearance we see is nothing else than *chalk*, and chalk is made up of lime and *carbonic acid.* Carbonic acid is, like common air, a colorless gas which we cannot see. It has the property of turning lime-water milky. It also puts out a flame of any kind. It was this gas which caused our candle to go out.

7. But how came the carbonic acid in the air in the bottle? Part of the wax of the candle has been

changed by burning into this carbonic acid gas. The *carbon* of the burnt wax is to be found again in this invisible gas. Some of the carbon you may notice going away as smoke or soot from the flame of the candle. If you quickly put a piece of white paper in the flame of the candle, so as not to burn the paper, you will see that it becomes stained with a black ring of soot, which is carbon.

8. Besides carbonic acid gas, there is another substance formed when the candle burns. You may think it strange that water is formed in the hot flame. Still this is really the case. If water comes from the flame, it will be in the state of hot steam which you know you cannot see. But you remember the steam from the spout of the tea-kettle became water when you held a cold spoon in the jet.

9. If the hot air coming from the burning candle contains steam, it will, when it is cooled, deposit the steam in the form of drops of water. All we need to do, in order to see whether steam is given off from a burning candle, is to hold a cold, dry tumbler over the flame. The bright glass soon becomes dimmed with little drops of water which bedew the inside of the tumbler.

10. If we should keep the tumbler cool all the time, we could get a small cup full of water by burning a candle. The water we should get in this way would

be just like all pure water, except that it would perhaps taste a little of soot.

Our question was, What happens when a candle burns? Let us see what we have now found out.

11. We have learned four things—

First, that the candle soon goes out if it is burned in a bottle of air.

Second, that a colorless, invisible gas, called carbonic acid, is formed in the bottle.

Third, that the carbonic acid gas comes from the carbon, or soot, contained in the wax.

Fourth, that water is also formed when the candle burns.

12. We have therefore learned that the wax of the candle has not been destroyed. It has changed its form, and has been turned into carbonic acid and water. No one could ever have found out that the solid candle could be changed into two such very different substances, one a gas and the other a liquid, except by making an experiment of the kind we have made.

13. Our experiment with the candle gives us at once the answer to another question—What becomes of all the wood or coal in a common fire in the stove? Most of it goes up the chimney as carbonic acid gas and steam, or vapor of water. A small part of it is left in the ashes in the stove.

But how does the fire burn?

14. The air, as we shall learn more fully by and by, is mainly a mixture of two gases. One of these is the colorless gas called *oxygen.* Now whenever anything burns, as a candle or a common fire, the substance of the candle, or the wood, or the coal, unites with the oxygen of the air. The carbonic acid and steam formed are the results of this union.

15. We have now learned two very important things about the burning of a candle. The first is, that no part of the candle is really lost or de stroyed. The second is, that the parts of the candle unite with the oxygen of the air. We have really learned more about fire than all the wisest men who lived more than one hundred years ago, ever knew.

1. Describe what happens when a bottle is put over a lighted candle.

2. What caused the candle to go out?

3. If you hold a piece of white paper for an instant in the flame of a candle, what can then be seen on the paper?

4. What substances are formed when a candle burns?

5. How can you show that there is water in the flame of a candle?

6. What becomes of the wood or coal burned in a stove?

7. What takes place when anything burns?

LESSON XIX.

THE LIFE OF A PLANT.

1. We cannot learn much, at this time, about the life of a plant, but we can learn enough to show us that it has a real life of its own, well worth knowing about. For a plant breathes, sleeps, feeds, and digests its food, just as truly as an animal does, though in a different way.

2. It works hard, both to get food for itself, and to make the air pure and fit for man and animals to breathe. It often lays by food for the winter, as man does. It sends young plants out, as parents send their children, to struggle for themselves in the world. And after living sometimes to a good old age, it dies, and leaves its place to others.

3. When a seed falls into the ground, so long as the earth is cold and dry, it lies like a person in a trance, with no signs of life. As soon as the warm, damp spring comes, and the busy little sunbeams pierce down into the earth, they wake up the little plant in the seed. They move to and fro the particles of matter in its tiny body, and cause them to seek out for other particles which they can lay hold of and join to themselves.

4. But these new particles cannot come in at the

roots, for the seed has none. Nor can they come in through the leaves, for these have not yet begun to grow. So the little plant begins by helping itself to the store of food laid up for it in the seed in which it is buried. Here it finds such things as starch, and oil, and sugar, all ready for it to use as food. It soon grows into a young plant with slender roots at one end, and a growing shoot, with leaves, at the other.

5. But how does it grow? What makes it become larger? If you peel an orange, and take the skin off a piece of the pulp carefully, you will see, inside, a number of long, slender bags, full of juice. These we call *cells*. The flesh of plants and animals is made up of cells like these, only of various shapes. You cannot, however, always see them with the eye alone. In the pith of the elder they are round and large, and may be easily seen. In the stalks of plants they are long, and lap over each other, so as to give the stalk strength to stand upright.

6. In the pulp of the orange these cells contain only sweet juice. But in other parts of the orange-tree, or any other plant, they contain a sticky substance with little grains in it. This substance is the *first form* of plant-life. It is alive and active. Under a microscope you may see in a living plant streams of the little grains moving about in the cells.

7. Now we can understand how a plant grows

Each little cell takes in starch and other food from the seed. In this way each cell soon grows too large for its covering. Then the active little substance at work in the cell divides the cell into two parts, and builds up a wall between them. Thus one cell be comes two. Each of these two cells again divides into two more, and in this way the plant grows larger and larger.

8. By the time it has used up all the food in the seed, it has sent roots, covered with fine hairs, down into the earth, and a shoot with little beginnings of leaves on it, up into the air. It is old enough now to begin to provide its own food. Until this time it has been living on the same kind of food that we eat. We find many seeds that are pleasant to eat, and useful to nourish us.

9. But now this store of food is used up. Upon what, then, is the plant to live? We cannot live, unless we have food that has once been alive, but plants can feed only upon gases and water and earthy matter. As soon as the plant has roots and leaves, it begins to make living matter out of matter that has never been alive. Through all the little hairs of its roots, it draws in water, and in this water are dissolved iron, and lime, and many other things that the plant uses for food.

10. But if the whole plant is made up of closed

bags, or cells, how is it to get this water up into the stem and leaves? It does it in a very curious way. The sap and juices of plants are thicker than water. As soon as the water enters the cells at the roots, it oozes up into the cells above, and mixes with the sap.

11. Then the matter in those cells becomes thinner than that in the cells above, and so it, too, oozes up. In this way, cell by cell, the water works its way up into the leaves. When it gets there, it finds our old friends, the sunbeams, hard at work, as usual. If you have ever seen a plant that was trying to grow in a dark cellar, you will know that in the dark, its leaves remain white and sickly.

12. It is only in the sunlight that the beautiful green tint is given to leaves. You remember that this green tint shows that the leaf has used all the sun-waves except those which make us see the green color. But why should it do this only when it has grown up in the sun-light?

13. The reason is this: when the sunbeam darts into the leaf, it sets all its particles quivering, and divides them into two kinds, which collect into different cells. One kind remains white. The other kind, near the surface, is altered by the sunlight, and by the help of the iron brought in by the water. This kind will have nothing to do with the green waves of

light, and throws them all back. Every little grain in these cells looks green, and gives the leaf its green color.

14. It is these little green cells that, by the help of the sun-waves, digest the food of the plant, and turn the water and gases into useful sap and juices. Now, every living thing wants carbon to feed upon. But plants cannot take carbon in by itself, because it is a solid. A plant cannot *eat;* it can only drink in fluids and gases. This is the work of the little green cells. They take in, or *absorb*, out of the air the carbonic acid gas. Then, by the help of the sunbeams, they tear the carbon and oxygen apart. Most of the oxygen they throw back into the air for us to use, but they keep the carbon for their own use.

1. What wakes up the seed lying in the earth?
2. Upon what does a plant feed when it begins to grow?
3. What is the flesh of plants and animals made up of?
4. What can be seen, by the help of a microscope, in the cells of a plant?
5. How does the plant grow larger and larger?
6. After the plant has roots and leaves, where does it get its food?
7. Why are the leaves of a plant green?
8. What part of the plant drinks in the water and gases that form its food?

PART II.

LESSON XX.

WHAT NATURE CAN TEACH US.

1. Have you ever carefully noticed the way in which the common things of every-day life are all connected? As far back as you can remember, you have been familiar with such things as air, water, sunshine, wind, rain, rivers, frost, and snow, for you have always seen them. They have grown so commonplace that you very seldom think about them. In this, young people are very much like older folks.

2. They seem, indeed, so natural and so necessary that you may even be surprised when any one asks you to tell what they are, or to give a reason for them. But suppose you had lived all your lives in a country where rain never falls, and were to be brought to such a country as this, it would make a great difference.

3. If you were to see a heavy shower of rain falling, would it not be strange to you, and would you not be very likely to ask the meaning of it? Or sup-

pose that a boy from some very warm part of the world were to visit this country in winter, and see for the first time the ground covered with snow, and the rivers covered with ice. Would you be surprised if he should show great wonder?

4. If he should ask you to tell him what snow and ice are, why the air is so cold and why the streams have become covered with ice, could you answer his questions? And yet these questions are about very common every-day things.

5. If you think about them you may find, perhaps, that it is not easy to answer them clearly and correctly. There are many questions that should be asked about all of these things. Listen to the wind as it blows, look at the clouds rolling overhead, or at the water flowing quietly along in the brook at your feet, and ask yourself, "Why and how is all this?"

6. Go out in the evening and see the dew that is gathering, drop by drop, upon the grass, or in the morning, and notice the delicate crystals of frost gleaming on every blade. How has this wonderful work been done? Man does none of it, neither could he stop it if he should try.

7. Where does the dew come from,—the rain, the snow, the water in the brook? What are the clouds floating in the sky? What becomes of the rain and

the snow? What is wind? Why are the pebbles in the brook so round and smooth? All around you there is abundant material for you to ask questions about.

8. Do not suppose that because a thing is common, it can be of no interest to you, or that, because you have seen it every day of your life, it does not deserve closer attention. It will reward you for all your pains. But how can you learn anything new about these common things?

9. You must first get into the habit of using your own eyes, and seeing for yourself what takes place in this wonderful world of ours. Besides the printed books that you use at home, or at school, there is the great book of Nature, where each of us, young and old, may read, and go on reading all through life. Even then we shall know only a small part of what it has to teach us.

10. It is a part of this great book—Air, Earth, and Sea—that we are about to look into. Do not be content with merely noticing that such and such events take place. Do not let a fact pass without trying to find out something about it. Get into the habit of asking Nature questions. Never rest until you learn the reasons for what you notice going on around you.

11. In this way even the most common things will come to have a new interest, and you will thus

learn to use your eyes quickly and correctly. This habit of observation will be of the utmost value to you, no matter what may be the path of life that lies before you.

12. Wherever you go there will be something for you to notice; something that will serve to increase the pleasure which the landscape affords. You will find that to use your eyes in this way, and to seek out the meaning of that which you see, will be neither a hard nor a dull task, and you will really be engaged in the study of science.

LESSON XXI.

THE AIR.

1. When we begin to look closely at the world around us, one of the first things to set us thinking is the air. We do not see it, and yet it is present wherever we may go. At one time it blows upon us in a gentle breeze; at another, it sweeps along in a fierce storm. What is this air?

2. Although we cannot see it, it is yet a real substance. If you fan yourself, you feel the air passing over your face. When you swing your arm rapidly, up and down, you feel the air on your hand. You can

feel it, though you cannot see it. You breathe it every moment.

3. You cannot get away from it, for it everywhere surrounds the earth. You can feel it when it moves. A light breeze, or a strong gale can no more be seen by the eye than still air, and yet we readily feel their motion. What makes the sails of a windmill go round and round? The wind, you say.

4. Yet the wind, which sometimes blows so hard as to uproot trees and wreck ships, is only air in motion. Thus one way in which we are shown the presence of the air is by its motion. But let us see whether we can find any other way by which air makes itself known.

5. Like common, visible things, air can be warmed and cooled. This may easily be shown by what takes place if you pass out of a warm room, on a winter's day, into the open air, when there is no wind. You feel a sensation of cold. Whence does this sensation come? Not from anything you can see.

6. Your feet, though resting on the frozen ground, or or the snow, are protected by your shoes, and do not feel the cold. It is the air, which is cold, and which surrounds you on all sides, that robs you of your heat. At the same time, you are giving off heat from your body into the air.

7. If, after standing a while in the chilly winter air,

you should return to the room, you would feel a sensation of pleasant warmth. Here, again, the feeling does not come from any visible object, but from the invisible air, which touches every part of your body. Your body now draws heat from the air.

8. Thus the changes of heat and cold are a second way in which we are shown the presence of the air. Now, how is it that the air should sometimes be warm and sometimes cold? Where does the heat come from? How does the air take it up? Let us see how the air in the warm room becomes heated.

9. In winter, although the air is keen and frosty outside, it is warm and pleasant indoors, because fires are kept burning there. The burning of wood and coal produces heat, and the heat thus given out warms the air. In this way the air in our houses is made warmer than the air outside.

10. But how does the air outside get its heat? Sometimes, in summer, this air is far hotter than that in our houses in winter when the fires are burning briskly. All this heat comes from the sun, which is a very large and very hot body, and is continually sending out heat in all directions.

11. But the sun does not shine all the time. Cloudy days are often quite warm; and we know that the nights are not always very cold. If our warmth depended upon the direct heat of the sun, alone,

we should be warm only when the sun shines. A cloudy day would then be a very cold one, and every night more frosty and cold than it ever is in winter.

12. There is a way in which the sun's heat is stored up so that it can be felt even when he is not shining. Let us see how this is done. If you place the back of a chair near the stove, you will find that, in time, it gets so hot you can hardly touch it. Remove the chair to a distant part of the room and it quickly cools.

13. A part of the heat from the fire has been absorbed by the chair and again given up. In like manner the ground is warmed by the heat of the sun. In some parts of the world it becomes so hot, at times, that one can hardly keep his hand upon it.

14. Have you never, in summer, found, lying in the sun, a stone that had become so hot you did not care to hold your hand upon it? Soil and stones absorb heat readily; they also give it up readily. But air keeps its heat longer than they do.

15. When they have been warmed by the sun they warm the air by contact with it. Even at night, when the soil and stones have become cold, the air a little above them is not so cold. On the other hand, when the surface of the ground is cold, it cools the air lying upon it. Thus the air is heated

or cooled as it lies upon a warm or cold part of the earth's surface.

1. In how many ways are we shown the presence of air?
2. What are these ways?
3. Why do we feel cold when we go out of doors in winter?
4. Why do we feel warm when we enter a warm room?
5. What is the source of the heat which warms the earth?
6. Why is this heat felt when the sun does not shine?
7. How is the air heated?
8. How is it cooled?

LESSON XXII.

THE WIND.

I.

1. The air lying next to a hot surface is heated; the air touching a cold surface is cooled. It is upon the difference of heat and cold in the air that the formation of wind depends. Hot or warm air is lighter than cold air. As a consequence of this difference, the light, warm air rises, and the heavy, cold air sinks.

2. You can easily satisfy yourselves of this by a simple experiment. Heat the end of a poker in the fire until it is red-hot. Hold some small pieces of very light paper, or other light substance, a few inches above the heated surface of the poker. The pieces of paper will be at once carried up into the air.

3. This happens because the air heated by the poker

immediately rises, and its place is taken by colder air which, on getting warmed, likewise ascends. The upward currents of air grow feebler as the iron cools, until, when the iron has become as cool as the air around it, they cease.

4. This is the principle on which fire-places are built. The fire is not kindled on the hearth, for, in that case, it would not get a sufficient draft of air underneath, and would be apt to go out. It is placed some way above the hearth, and over it there is an opening into the chimney.

5. As soon as the fire is lighted, the air above it gets warmed, and begins to rise. The air in the room is then drawn in from below to take the place of that which rises. All the air that lies above the fire gets warmer and lighter; it therefore passes up the chimney, carrying the smoke with it.

6. You will understand that, though a bright, blazing fire is a pleasant sight in winter, we do not get all the heat that it gives out. On the contrary, a great deal of the heat goes up the chimney, of which some serves to warm the walls, while much escapes and serves only to warm the air outside.

7. What happens in a small way in our houses takes place on a far larger scale in nature. As you have already learned, the sun is the great source of heat which warms our globe. While the heat of the sun

is passing through the air, it does very little in the way of warming it.

8. The heat goes through the air, and warms the surface of the earth. You know that, in summer, the direct rays of the sun are sometimes hot enough to burn your face. Yet, if you put even a thin sheet of paper over your head, so as to cut off these rays, the feeling of burning heat at once passes away, although the same air is playing about you all the time.

9. Both land and water are heated by the sun's rays, and the same change in the air that we notice at our firesides then takes place. The layer of air next the earth becomes warmed. As it thereby grows lighter it rises. Colder air blows in from around, to take its place, and this flowing in of air is *wind.* Wind is nothing more than air moving along the surface of the earth.

10. Why does the wind blow sometimes one way, and sometimes another, and sometimes not at all? What makes the air restless? Why should it not lie still all round the earth? It is restless because its atoms are kept pressed together, near the earth, by the weight of the air above.

11. When they can find more room, they take every opportunity to spread out, and rush into this vacant space, and this rush of air we call a wind. But how came they to find any vacant space before them? To

answer this question we must go back to the active little sunbeams. When they come pouring down upon the earth, you remember, they pass through the air, almost without heating it.

12. But they heat the surface of the earth, which, in turn, heats the air near it, forcing its atoms apart and making it lighter. Now, just as a cork rises in water so this heated air rises through the cold air above it; then the cold air, whose atoms are struggling and trying to get away, rushes in and fills the space.

1. On what does the formation of wind depend?
2. Why does warm air rise?
3. Why are the pieces of paper held over a heated poker carried up into the air?
4. Why is not a fire kindled on the hearth?
5. Why do we not get all the heat given out from an open fire?
6. What is wind?

LESSON XXIII.

THE WIND.

II.

1. It is easy for you, now and then, to watch how wind arises. Perhaps you live on the sea-coast, or, during the summer, you spend some time there. In

the morning, and the early part of the day, you will often notice a gentle breeze blowing from the land out to the sea. As the day advances, and the heat increases, this wind dies away.

2. But towards evening, another breeze may be noticed springing up from the opposite direction, and blowing with a delicious coolness from the sea to the land. These breezes are the result of the unequal heating and cooling of the sea and land.

3. Let us try to understand how this takes place. On a hot day you find that stones, soil, or other parts of the land, get very warm under the sun's rays. If you bathe in the sea at that time, its waters feel pleasantly cool. This shows that the land becomes hot more quickly than the sea.

4. After such a hot day you will find that, at night, the surface of the land becomes much colder than the sea, because it parts with its heat more quickly than the sea does. By day, the hot land heats the air lying above it, and makes it lighter, so that it ascends.

5. The air lying on the sea, which is cooler and heavier, then flows landward, as a cool and refreshing sea-breeze, to take the place of the rising air. At night this state of things is reversed. Then the air, which lies on the chilled land, being colder and heavier than that which covers the warmer sea, flows seaward as a cool land-breeze.

6. Take a school globe and notice some of the lines that are drawn round it. Midway between the two poles you will find a line running round the most projecting part of the globe. This line, called the *Equator*, divides the globe, as you see, into halves, or *hemispheres.*

7. Over the parts of the earth which this imaginary line crosses, and for some way on each side, the sun shines with intense heat all the year round. The air is constantly heated to a high degree, and streams upwards in ascending currents.

8. But, while the hot air along this central belt mounts up into the higher regions of the atmosphere, the cooler air from north and south flows in along the surface to supply its place. This constant streaming of air into the equatorial regions forms what are known as the *Trade Winds.*

9. The steadiness of these winds, and the way in which they can be depended upon in navigation, led, long ago, to their being called by their present name. It is only in the two great oceans, the Pacific and the Atlantic, however, that they have their full scope. Elsewhere they are more or less diverted from their course by the unequal distribution of land and sea.

10. In our country the winds are by no means so regular and constant. If you look at the map and

mark the position of the United States upon the surface of the earth, you readily notice some reasons why our winds should be variable.

11. Lands much colder than ours spread to the north; others, much warmer, lie to the south. Lofty mountain ranges, beautiful valleys, large plains, and broad lakes break up the surface of the interior. With such a varied surface receiving the sun's heat, we may expect to find that sometimes a warm wind blows from one quarter, and sometimes a cold wind from another.

12. We have not time to travel farther with the moving air, though its journeys are very interesting. Every breath of wind that blows past us tells us that the air is always moving to and fro over the face of the earth. When we think how many impurities it must carry away, as it sweeps over crowded cities, we can see how, in this one way alone, it is a great blessing to us.

13. When you read about the Trade Winds, or others, picture to yourself warm air, made light by heat, rising up into space, and cold air expanding and rushing in below to fill its place. If you do this, you will not find the study of the moving currents of the atmosphere so dull and dry as many people suppose it to be.

1. How is a sea-breeze formed ?
2. How is a land-breeze formed ?
3. What are the Trade Winds ? How are they formed ?
4. Why are they called Trade Winds ?
5. Where do they blow with regularity ?
6. Why not elsewhere ?
7. Give some reasons why the winds, where you live, are not uniform.
8. Name one particular in which the wind is a great advantage to us.

LESSON XXIV.

WHAT AIR IS.

1. Did you ever sit on the bank of a river, in some quiet spot, where the water is deep and clear, and watch the fishes swimming lazily along ? Perhaps you have done so, and have wondered why the fishes should live in the water while you live in the air.

2. We can see the fish because we are above the water in which they live, and that is a liquid which our eyes can perceive. But the air is a gas, and invisible to us. Let us suppose, for a moment, a being, whose eyes were so made that he could see gases as we see liquids, to be looking down, from the regions of space, upon our earth.

3. He would see an ocean of air all round the globe, with birds flying about in it, and people walking upon

the bottom of it, just as we see fish swimming along the bottom of a river. It is true, he would never see even the birds come near to the surface, for the highest-flying bird, the condor, never soars more than five miles from the ground.

4. Our atmosphere is at least one hundred miles high, and he might call us deep-air creatures, just as we talk of deep-sea animals. If we imagine that he could fish in this air-ocean, and should pull one of us out of it into space, he would find that we should gasp and die just as fishes do when pulled out of the water.

5. He would also observe very curious things going on in our air-ocean. He would see large streams and currents of air, which we call winds, flowing in various directions. Near the earth, thick mists could be seen forming and then disappearing; these would be our clouds. From them he would see rain, hail and snow falling to the earth.

6. Can we find out what air is? At one time it was thought that it was a simple gas, and could not be separated into different parts. It has, however, been shown that air is made of two gases mingled together. One of these gases, called *oxygen*, is used up when anything burns. The other, called *nitrogen*, is not used, and only serves to separate the minute atoms of oxygen.

7. By careful experiments it has been found that, for every pint of oxygen in the air, there are nearly

four pints of nitrogen. The active, restless atoms of oxygen are scattered about, floating in the sleepy, inactive nitrogen. These atoms of oxygen we use up when we breathe, and hence it is necessary that we be constantly supplied with pure fresh air.

8. If we were shut up in a room, into which no air from without could possibly find its way, we should soon use up all the oxygen in the air of the room. Then, suffocation and death would follow. Do you see, now, how foolish it is to live in close rooms, or to hide your head under the bedclothes when you sleep?

9. Perhaps you will say, "If oxygen is so useful, why is not the air made entirely of it?" But let us think for a moment. If there were such an immense quantity of oxygen how fearfully fast everything would burn! Our bodies would soon rise above fever heat from the quantity of oxygen we should breathe in.

10. All fires and lights would burn furiously. In fact, a flame once lighted would spread so rapidly that no power on earth could put it out, and everything would be destroyed. The lazy nitrogen is very useful in keeping the atoms of oxygen apart. Even when a fire is very large, we have time to put it out before it can draw in so much oxygen from the surrounding air as to get beyond control.

11. When we examine ordinary air very carefully, we find small quantities of other gases in it. First,

there is *carbonic acid gas.* This is the bad gas which we give out in our breath, after we have burnt up the oxygen, with the carbon of our bodies, inside our lungs. This gas is also given out from everything that burns.

12. If only animals lived on the earth, the carbonic acid would soon poison the air. But the plants lay hold of it, and, in the sunshine, they are able to separate the oxygen and carbon. They use the latter, and throw back the former for our use. Secondly, there are very small quantities of *ammonia* in the air, which is also useful to plants.

13. Lastly, there is a great deal of water in the air, floating about as invisible vapor, or *water-dust.* These gases in the atmosphere are, however, present in very small quantities. The bulk of the air is composed of oxygen and nitrogen. So, you see, we are right in picturing this invisible air all around us as, mainly, a mixture of two gases.

1. What is the air?
2. Of what is it mainly composed?
3. Name some other gases in the air.
4. How high is our atmosphere?
5. What purpose does the nitrogen in the air serve?
6. Why do we need fresh air?
7. If air were composed wholly of oxygen what would happen?
8. To what are the carbonic acid and the ammonia in the air useful?

LESSON XXV.

THE VAPOR IN THE AIR.

1. Did you ever think of following a drop of water on its travels? Have you any idea whence it started, where it has been, what changes it has gone through? Do you know what work it has been doing for all the long ages that water has lain on the face of the earth?

2. Let us try to understand how two invisible workers, the sunbeams and the air, deal with the drops of water. And, first of all, let us try to see how the vapor of water gets into and out of the air. In doing this we shall find that great questions in science often admit of being simply and readily illustrated by the most familiar things.

3. In a warm room, where a good fire has been burning all day, you would suppose that the air must be dry. Carry a tumbler of ice-cold water into the room, and mark what happens to it. You will see the outside of the glass soon covered with a fine film of mist.

4. In a little while small drops of water will form out of this film. These will go on growing until, perhaps, some of them unite and trickle down the side of the tumbler. You may have noticed, too, that on cold nights the windows of sitting-rooms, or crowded

public halls, are sometimes found streaming with water on the inside.

5. Now, in these cases, where does the moisture come from? Certainly not out of the glass. It is derived from the vapor of water everywhere present in the air. But how does the vapor get into and out of the air? If you pour a little water into a plate, and set it in the open air, you will see, after a time, that the water has sensibly diminished.

6. If the plate be left out long enough, the water will entirely disappear. Where has it gone to? Into the air. What takes place with the small quantity of water in the plate, goes on from every body of water on the face of the earth. Without any fuss, or noise, or sign of any kind, the water is being drawn up invisibly into the sky.

7. Every day, and all day long, the air is carrying off water from the surface of springs, rivers, ponds, lakes, seas, the great oceans, and even from the surface of ice and snow. This process is called *evaporation*, and the water which passes into vapor is said to evaporate.

8. It has been calculated that three-quarters of an inch of water is carried off from the surface of the Indian Ocean in one day and night. At this rate, as much as twenty-two feet, or a depth of water about twice the height of an ordinary room, is silently and

invisibly lifted up from the whole surface of this ocean in one year.

9. You must remember, however, that the Indian Ocean is situated where the sunbeams are most active, and in one of the hottest parts of the earth's surface. But even from that part of the sea near our own country, many feet of water are drawn up into the atmosphere every year. What becomes of all this water?

10. Let us follow it as it struggles upwards from the sea to the sky, rising far above our heads and above the tops of the highest mountains. As the water-laden air rises, its particles, no longer so much pressed together by the weight of air above them, begin to separate. The air becomes colder, and the invisible vapor forms into tiny water-drops.

11. As the air rises higher yet, and becomes still colder, the condensed vapor gathers into visible masses, which we can see hanging in the sky, and which we call *clouds*. When these clouds are highest they are about ten miles from the earth. When they are made of heavy drops, and hang low down, they sometimes come within a mile of the ground.

12. Look up at the clouds as you go home, and think that the water of which they are made, has all been drawn up invisibly through the air. Perhaps it has traveled many hundreds of miles, for we know that air, in the state of wind, travels all over the

world, rushing in to fill spaces left by rising air, wherever they occur.

13. These clouds above us now may be made of vapor collected in the Atlantic Ocean, or in the Gulf of Mexico, or may be made of chilly particles gathered from the surface of ice or snow in Greenland, and brought here by the moving currents of air. Only, of one thing we may be sure,—they came from the water of our earth.

14. Sometimes, if the air is warm, these particles of water in the air may travel a long way without ever forming into clouds. On a hot, cloudless day, the air is often very full of vapor. Then, if a cold wind comes sweeping along, high up in the sky, and chills this vapor, it forms into great bodies of clouds, and the sky is overcast, or clouded.

15. At other times, clouds hang lazily in a bright sky. These show us that, just where they are, the air is cold. It has turned the invisible vapor, rising from the ground, into visible water-dust, so that we see it as clouds, in the very places where the change is made. Such clouds form often on a warm, still summer's day.

16. They are shaped like masses of wool, and end below in a straight line. They are not merely hanging in the sky; they are really resting upon a tall column of invisible vapor which rises from the earth. That straight line marks the place where the air be-

comes cold enough to turn the vapor into visible drops of water.

1. Where does the moisture come from, which we see on the inside of windows?

2. What is evaporation?

3. What depth of water is said to evaporate from the Indian Ocean in 24 hours?

4. Does as much evaporate from the surface of the Atlantic Ocean in the same time? Why?

5. When rising vapor condenses in the air into visible masses, what are these masses called?

6. How high above the earth are they?

7. Whence does the water of which they are composed come?

LESSON XXVI.

THE DEW.

1. The vapor in the air, you must remember, is always invisible, even when the air contains all it can hold. It is only when it passes back into the state of water, as in mist, dew, clouds, or rain, that we actually see anything. When this takes place, the vapor is said to be *condensed*, and the process is called condensation.

2. The quantity of vapor which the air can contain, varies according to its temperature. Warm air will hold more vapor than cold air. This can be shown in

a simple way. In breathing you exhale, or throw out, with each breath, a quantity of vapor. When the air is warm, this invisible vapor mixes with the outer air, and is kept dissolved there.

3. If you cool the breath as it leaves your mouth, the vapor is at once condensed into visible moisture. Take a mirror, or any other cold surface, and breathe on it. The vapor in your breath at once shows itself in a thin film of mist upon the surface of the glass.

4. Why is this? It is because the air in contact with the cold surface is chilled and cannot hold all its vapor. A part of it is condensed. In winter our breath often becomes visible. The cold air around us condenses the vapor as it comes from the mouth, and forms the fine cloud, or mist, which appears with each breath that we exhale.

5. As the air is cooled, its power of retaining vapor diminishes. When it becomes so cold that it can no longer hold its vapor, then the vapor is condensed, and becomes visible. After sunset, when the sky is clear, you know that the grass is often wet with dew.

6. In the morning you may sometimes see mists hanging over woods and streams and hills. Gradually they melt away, as the sun mounts in the sky. These are all examples of the condensation of vapor, which results, as we have seen, from a cooling of the

air. But when vapor is condensed it does not at once take the form of running water.

7. The cold glass brought into the warm room has, first, a fine film of mist formed upon it, and then, by degrees, the clear drops of water come. In reality mist is made up of exceedingly small particles of water. It is the running together of these that forms the larger drops.

8. So in nature, when condensation occurs on a large scale, the vapor first appears as a fine mist. This, remember, is always the result of cooling; so that, whenever you see a mist or cloud forming, you may conclude that the air in which it lies is being cooled.

9. Have you ever thought how dew forms in the evening, or at night, upon the grass and leaves? In the morning you have, no doubt, often noticed the sparkling little dew drops. At night, when the sky is clear, the earth throws off heat rapidly; that is to say, a great part of the heat which it has received from the sun during the day leaves it.

10. Grass especially gives up its heat quickly; the blades are thin and almost all surface, and on this account they part with their heat faster than they can draw it up from the ground; hence they become cold.

11. Now the air lying just above the grass is full

of invisible vapor. The cold of the blades, as it touches the vapor, chills it. The particles of water being no longer able to keep apart, unite and form tiny drops on the surface of the leaves. This is *dew*, and *frost* is simply frozen dew.

12. The dew is all derived from the air by condensation, exactly as we saw the film of mist form upon the cold tumbler in the warm moist air of a room. In fact, that film of mist on the tumbler was really dew, and all dew is formed in the same way, and by the same cause.

13. Some night, when a heavy dew is expected, try the experiment of spreading a piece of cloth over some part of the grass, supporting it at the four corners with sticks, so that it forms an awning. Though there may be plenty of dew on the grass all around, you will find scarcely any under this awning.

14. The reason of this is, that the cloth checks the heat as it rises from the earth. The blades of the grass do not become cold enough to condense the vapor in the air, and draw the particles together into drops on their surface.

15. If you walk off the grass on to the gravel path, you find no dew there. Why is this? Because the stones in the path can draw up heat from the earth below as fast as they give it out, and so they never

become cold enough to chill the air which touches them.

16. On a cloudy night you will find little or no dew on the grass, even. This is because the clouds shut in the heat rising from the earth, just as the little awning did, and so the grass does not become cold enough to draw the water-drops together.

17. After a hot, dry day, when the plants and leaves have become thirsty, and when they have but little hope of rain to refresh them, they are able, in the evening, to draw the little drops of dew from the air, and drink them in before the rising sun comes to drive them away.

1. What is condensation?

2. How does the quantity of vapor the air can hold, vary?

3. Why does a mist appear on the window-glass when you breathe on it?

4. Why is our breath often visible in winter?

5. What effect does cooling the air have on its power to hold vapor?

6. What does condensation in the air always result from?

7. Explain how dew forms on the grass and leaves. What is frost?

8. Why is no dew formed on a gravel path?

9. Why does not dew form on a cloudy night?

LESSON XXVII.

MIST, FOG, CLOUDS AND RAIN.

1. Another way in which a cold surface of the earth may cause condensation of vapor is shown by what takes place among the mountains. When a warm, moist wind blows upon a chill mountain top, the air is cooled. The vapor then becomes visible in the form of a mist or cloud.

2. You can often see that the cloud is quite solitary. Sometimes it even shapes itself to the form of the ground, as if it were a sort of fleecy cap drawn down over the mountain's head.

This is usually well marked in the morning.

3. As day advances, the ground, warmed by the sun, no longer cools the air, and hence the mist is gradually absorbed again by the atmosphere. By and by, at the coming on of night, the ground is once more cooled. If there should then be vapor enough in the air, the mist will form and the mountain put on his cap again.

4. Cold air, as well as cold ground, condenses the vapor of warmer air. If you watch what goes on along the course of a river, you may often see examples of this kind of condensation. The ground on either side of the river parts with its heat, after sundown, sooner than the river itself does.

5. The ground, consequently, cools the air above it more than the air above the river is cooled. This colder air from either side moves over and takes the place of the warmer damp air lying on and rising from the river. Condensation then takes place, in the form of the mist, or river-fog, which so often hangs at night and early morning over streams.

6. It is not on the ground, however, but up in the air that the chief condensation of vapor takes place. No feature of every-day occurrence is more familiar than the clouds, which are the result of this condensation. A cloud is merely a mist formed by the cooling of warm, moist air, when it loses its heat from any cause.

7. If you watch what goes on in the sky, you may often see clouds in the act of forming. At first a little flake of white appears. By degrees this grows larger. Other cloudlets arise and flock together, until, perhaps, the sky is quite overcast with heavy clouds.

8. On a summer morning the sky is often free from clouds. As the day advances, and the earth gets warmed, more vapor is raised. When this vapor, borne upward by the rising air-currents, reaches the higher and colder parts of the atmosphere, it is chilled into the white, fleecy clouds which we sometimes see forming about midday, and in the afternoon.

9. Towards evening, less evaporation takes place.

The clouds cease to grow, and gradually lessen in size until, at night, the sky becomes quite clear again. They have been dissolved by descending, and by coming in contact with the warm air near the earth.

10. You have often noticed that clouds move across the sky. They are driven along by upper currents of air, or winds. Of course, the stronger these currents are the faster the clouds travel. In this way the sky is sometimes overcast with clouds that have come from a distance.

11. In following our drop of water on its travels, we have traced the vapor which the sun's heat raises from the rivers, lakes, and seas of the earth until we have found it condensed into visible form in the clouds.

12. But the clouds do not remain always hanging in the sky. Sometimes they melt away and are dissolved into invisible vapor again. But they often disappear in another way. They let their moisture fall through the air to the earth in the form of rain and snow.

13. In the illustration of the glass of cold water brought into the warm room, you remember that the film of mist formed upon the glass was found to gather, by degrees, into drops which trickled down the cold surface.

14. Now, the mist on the glass and the cloud in the

sky are both formed of minute particles of water separated by air. It is the running together of these particles which forms the drops. In the one case, the drops run down the cold glass. In the other case, they fall as drops of rain through the air.

15. The minute particles of the cloud, as condensation proceeds, gather more moisture round them, until at last they form drops of water too heavy to hang any longer in the air. These then fall to the earth as rain-drops.

1. How does the mist, sometimes seen on a mountain top, in the morning, disappear?

2. Explain the formation of river-fog.

3. Where does condensation of vapor mainly take place?

4. Explain the formation of the clouds, sometimes seen at mid-day, and in the afternoon of a summer's day.

5. What makes the clouds move across the sky?

6. How do clouds disappear?

7. When do the drops of water fall as rain?

LESSON XXVIII.

SNOW, ICE, HAIL AND SLEET.

1. There is another important form in which the moisture of the clouds may descend to the surface of the earth. When the weather is cold enough, flakes of snow fall to the ground. If you bring snow in-

doors, it soon melts into water. If you expose this water for a time, it evaporates.

2. Snow, water, and aqueous vapor (vapor formed from water), are thus only different forms of the same substance. Water is found in three different forms: the gaseous,—as vapor,—the liquid, and the solid. Snow is an example of the solid form.

3. On a frosty night pools of water are covered with a hard transparent crust of what is called *ice*. The greater the cold the thicker will the crust be, until, perhaps, the whole of the water in the pools may become solid.

4. If you take a piece of this solid substance, you find it to be cold, brittle and transparent. Brought into a warm room it soon melts into water, and you may drive off the water into vapor.

5. Ice is the general name given to water in the solid form. Such forms as snow and hail are only different appearances which ice puts on. Whenever water becomes colder than a certain temperature, it passes into ice, or *freezes*.

6. The upper layers of the atmosphere are much colder than the temperature at which water freezes. When condensation takes place in the freezing atmosphere of these high regions, the particles of water-vapor are built up into minute, solid crystals of snow, forming the snow-flake. This is so white and pure

that, when we want to speak of anything being spotlessly white, we often say it is "as white as snow."

7. Even in summer, the fine, white cloudlets which you see floating at great heights are probably formed of snow. In countries such as ours, where, in winter, the air nearest the earth is sometimes very cold, the snow falls to the ground and lies there as a white covering, until returning warmth melts it away in the spring.

8. Besides rain and snow, the moisture of the air takes sometimes the form of *hail*, which consists of little lumps of ice like frozen rain, and of *sleet*, which is partially melted snow. If the falling rain-drop meets with such a cold blast of air as to bring it to the freezing-point, it will freeze into a hailstone.

9. Let us gather together the sum of what has been said about the aqueous vapor of the air. We have learned that, from every sheet of water on the face of the globe, vapor is constantly rising into the air, and that when condensed into visible form, this vapor again appears as dew, mist and cloud.

10. We have also learned that the vapor of which the clouds are formed is resolved into rain or snow, and descends to the earth again in one or other of these forms. Thus a circulation of water is kept up between the solid earth and the air above.

11. This circulation plays a very important part in making the earth a fit habitation for living things. It washes the air, clearing away impurities, such as those which rise from the chimneys of a town. It moistens and quickens the soil, which it renders capable of supporting vegetation. It supplies springs, brooks and rivers. In short, it is the very mainspring of all life upon the globe.

1. In how many and in what forms is water found?
2. Of what are the small, white cloudlets probably formed?
3. What is hail? How is it formed?
4. Tell the substance of what has been said of the aqueous vapor of the air.
5. Name the various forms this vapor takes.

LESSON XXIX.

WHAT BECOMES OF THE RAIN?

1. When a shower of rain falls, the ground does not become dry the moment the shower is over. If heavy rain continues for hours together, the whole country round may be flooded, and, perhaps, remain so for days after the rain has ceased. In time, however, the ground does become dry again.

2. What has become of the water? The disappearance of part of it, but only a very small part, is due

to evaporation. Most of it goes out of sight in other ways. It does not at once disappear, but it begins another kind of circulation.

Notice what happens during a shower of rain.

3. If the shower be heavy, you will notice little rivulets of muddy water flowing down the streets or roads, or from the ridges of the fields. Follow one of these rivulets. It leads into some drain or brook, that into some larger stream, and the stream into a river.

4. The river, if you follow it far enough, will bring you to the sea. Now think of all the brooks and rivers of the world, and you will at once see how great must be that part of the rain which flows off the land into the ocean.

But does the whole of the rain flow off at once, in this way, into the sea?

5. By no means, as you can easily prove. Suppose that, after the shower, you dig up a spadeful of earth. Do you find the ground dry? No; because some of the rain has soaked into the earth. If you dig deep enough, you will find that the ground underneath is not merely damp, but that it contains plenty of water.

6. You may think that the water which sinks underground must be finally withdrawn from the general circulation that was spoken of in the last

lesson. When the water sinks below the surface, how can it ever get up to the surface again? What would happen if all the rain which sinks into the ground were forever removed from the surface circulation?

7. The quantity of water on the earth's surface would be constantly and visibly diminishing. The seas would be getting narrower and shallower; the rivers and lakes would be drying up. But no such changes, so far as can be seen, are really taking place.

8. If any of the water which sinks into the earth is never restored to the surface again, it must be a very small part. The circulation of water between the air, the land, and the sea, goes on, from year to year, without any perceptible change.

9. There must be, therefore, some means by which the water underground is brought back to the surface. This is done by *springs*, which gush out of the earth, and bring up water to feed the brooks and rivers, by which it is borne to the sea.

10. The rain which falls upon the sea is, however, the largest part of the whole rain-fall of the globe. Why is this? Because, as you have already learned, the surface of the sea is about three times as great as that of the land.

All this rain gradually mingles with the salt water.

11. In this way it helps to make up for the loss

which the sea is always suffering by evaporation; for it is from the sea that most of the vapor of the atmosphere is derived.

You can now answer the question, What becomes of the rain?

12. Most of it sinks into the earth, and afterwards comes out again in springs. Part of it runs off the surface into brooks and rivers. Of this part, that which is not evaporated works its way over the land, and falls at last into the sea.

1. What becomes of the water which falls on the earth in the form of rain?
2. What is a rivulet? How is it formed?
3. What is a river? How is it formed?
4. What is a spring? Where does its water come from?

LESSON XXX.

HOW SPRINGS ARE FORMED.

1. There are two distinct courses which the rain-fall takes—one below ground, and one above. Let us follow, first, the course of that part of the rain which sinks into the ground.

2. If we observe the soils and rocks of a country, we shall see that they differ greatly from one another

in hardness, and in texture, or grain. Some are quite loose and porous; others are tough and close-grained. They consequently differ much in the quantity of water they allow to pass through them.

3. A bed of sand, for example, is *pervious;* that is, will let water sink through it freely, because the little grains of sand lie loosely together. They touch one another only at some points, leaving empty spaces between, through which the water readily finds its way.

4. A bed of clay, on the other hand, is impervious. It is made up of very small particles, fitting closely to one another, and, therefore, wherever such a bed occurs, it offers resistance to the free passage of the water in any direction.

5. The water is unable to sink through it from above, on the way down, or to pass through it from below, on the way up to the surface. Thus hindered by the clay, it is forced to find another line of escape.

6. You know that sandy soils are dry, while clay soils are wet. The rain easily, and at once, sinks through the sand. Clay soils are wet because they retain the water. Their close texture prevents the water from freely descending into the earth.

7. When water from rain, or melted snow, sinks below the surface into the soil, or into rock, it does not remain at rest there. If you were to dig a deep

hole in the ground, you would find that water would soon begin to trickle out of the sides of the hole, and gather into a pool at the bottom.

8. If you dipped the water out, it would still keep oozing from the sides, and the pool would soon be filled again. This shows that the underground water will readily flow into any open channel that it can reach. Holes, called *wells*, are dug to catch this water. Mines, quarries, and deep excavations or holes of any kind, are usually troubled with it, and need to be kept dry by having it pumped out.

9. The rocks beneath us, besides being, in many cases, porous in their texture, as sandstone, are all more or less traversed by cracks. Sometimes these are mere lines, like those of a cracked window-pane, but sometimes they are wide and open clefts and tunnels. These numerous passages serve as channels for the underground water.

10. Hence, although a rock may be so hard and close-grained that water does not soak through it at all, yet, if there are many of these cracks in it, it may allow a large quantity of water to pass through.

11. Limestone, for example, is a very hard rock; through its grains water can make but little way. Yet, it is very full of cracks, or "joints," as they are called. These joints are often so wide that they give passage to a great deal of water.

12. In hilly districts we sometimes find places that are marshy and wet, even when the weather has long been dry. Whence do they get the water? Plainly, not directly from the air; for, in that case, the rest of the ground would also be wet. They get it, not from above, but from below.

13. The water oozes out of the ground; and it is this constant outcome of water from below that keeps the ground wet and marshy. In other places we see that the water does not merely soak through the ground, but it gives rise to a little streamlet of clear water.

14. If you follow such a streamlet up to its source you will find that it comes gushing out of the ground as a *spring*. Springs are, then, the natural outlets for underground water.

1. In what respects do the soils differ? In what respects do rocks differ?

2. Why does water sink more quickly through a bed of sand than through a bed of clay?

3. Where does the water come from which gathers in a hole dug in the ground?

4. Is this gathering of water ever useful to us?

5. Name cases where it is a hindrance.

6. How does water from the surface get below rocks?

7. What keeps marshes wet in dry weather?

LESSON XXXI.

THE WORK OF WATER UNDERGROUND.

1. No form of water seems purer than the clear, crystal spring, as it comes bubbling out of the earth. Perfectly pure water should consist only of two elements, or gases,—*Oxygen* and *Hydrogen.* One of these elements is the same gas we found in the Air. But in the water of every spring, no matter how clear and sparkling it may be, there is something else.

2. If you take a quantity of perfectly pure water, and boil it down, you may drive the whole of it off in steam. Not a particle of anything will be left behind. Rain takes up a little impurity from the air, yet it may be regarded as very nearly pure water.

3. But if you boil down a quantity of spring water, you will find some solid matter. If rain is water merely in a state of purity, and, if, after journeying up and down underground, it is always more or less mingled with other materials, it must get these materials from the rocks through which it travels.

4. These materials are never visible to the eye, for they are held in what is called *chemical solution.* If you put a few grains of salt or sugar in a cup, and pour water over them, they are dissolved in the water and disappear. They enter into union with the water.

You cannot see them, but you can know of their presence by the taste that they give to the water which holds them in solution.

5. So water, sinking into the earth, dissolves a little of the substance of the underground rocks. This dissolved material it brings up to the surface of the ground. But you may say, salt and sugar are easily acted on by water, hard rocks are not; how is it that the springs can get their solid impurities from rocks?

6. You remember that one of the ingredients in the air is carbonic acid gas. In falling through the atmosphere rain absorbs a little air. As ingredients of the air, a little carbonic acid gas, particles of dust and soot, and other substances floating in the air, are caught up by the descending rain.

7. In this way the rain, as it were, washes the air, and tends to keep it much more wholesome than it would otherwise be. But rain gathers impurities not alone from the air; it gets many more when it reaches the soil and sinks into it.

8. If you take up a little earth from a field or garden, you may notice tiny fibres and decaying roots in it. It contains always more or less of such matter, and, therefore, carbonic acid. Armed with the carbonic acid which it gets from the air, and with the larger quantity which it abstracts from the soil, rain-

water is prepared to attack rocks, and to eat into them in a way pure water could not do.

9. Water containing carbonic acid has a remarkable effect on many rocks, even on some of the hardest. It dissolves more or less of their substance and removes it. When it falls, for instance, on chalk, or limestone, it almost entirely dissolves the rock, and carries it away in solution, though still remaining clear and limpid.

10. In regions where that rock abounds, this action of water is shown in the fact that the springs are always *hard;* that is, they contain much mineral matter in solution. Rain-water, and springs which contain little mineral matter, are termed *soft.*

11. Every spring throughout the world is busy bringing up materials of some kind to the surface. It is plain, therefore, that the amount of rock dissolved beneath the surface of the ground, and removed by the water, must, in the end, be very great.

12. You can now see how there should be channels and tunnels, for the water underground. The water is always eating away a little of the surface over which it flows, thereby widening the cracks and crevices, and changing them, by degrees, into wider passages. In this way, even large caverns, many feet high and many miles long, have been formed underneath the surface, in different parts of the world.

1. Of what two gases is pure water composed?
2. Why is the water of springs and rivers impure?
3. Why do we not see the impurities in the water, which it gathers from the rocks?
4. How does water penetrate hard rocks?
5. How does hard water differ from pure rain-water?

LESSON XXXII.

THE FORMATION OF BROOKS AND RIVERS.

I.

1. In an earlier lesson we have traced the course of the rain that sinks into the ground, until it comes to the surface again in springs. We have now to trace, in a similar way, the course of the other portion of the rain-fall,—that which flows along the surface of the ground in brooks and rivers.

2. You cannot readily meet with a better illustration of this subject than that which is furnished by a gently sloping road, during a heavy shower of rain. Let us suppose that you know such a road, and that, just as the rain is beginning to fall, you stand at some part where the road has a well-marked descent.

3. At first, you notice that each of the large, heavy drops makes in the dust, or sand, a little dint, or rain-print. As the shower increases, these rain-prints are effaced, and the road soon streams with water.

Now, notice in what manner the water moves, as it begins to flow along the surface.

4. Looking more closely at the road, you see that it is full of little rough places. At one place there is a long rut; at another, a projecting stone. There are many more inequalities, which your eye could not easily detect, when the road was dry, but which the water at once makes plain.

5. Every little depression and projection affects the flow of the water. You can see how the rain-drops gather together into slender streamlets of running water, which course along the hollows. You notice, too, how the jutting stones and pieces of earth seem to turn these streamlets, now to one side and now to another.

6. Towards the top of the slope only feeble rivulets of water are to be seen. Farther down they become fewer in number, and, at the same time, larger in size. They unite as they descend. The larger and swifter streamlets at the foot of the descent are thus made up of a great many smaller ones from the higher parts of the slope.

7. Now this sloping roadway, with its branching rills made by the rain flowing down the slope and uniting into larger streams, as they advance, will repay close and careful observation. It shows very well the way in which the rain runs off the sloping surface of a country or a continent.

8. Why does the water run down the sloping road? Why do rivers flow? Why do their waters move constantly in the same direction? They do so for the same reason that a stone falls to the ground when it drops out of your hand. They are drawn by that attraction towards the center of the earth to which the name of *gravity* is given.

9. Every drop of rain falls from the clouds to the earth because it is drawn downwards by the force of this attraction. When it reaches the ground it is still, and as much as ever, under the same influence; and it flows downwards in the readiest channel it can find.

10. Its fall from the clouds to the earth is direct and rapid;—its descent from the mountains to the sea, as part of a stream, is often long and slow. The cause of the movement is the same in either case. The winding to and fro of streams, the rush of rapids, the fall of cataracts, the noiseless flow of the deep, silent currents,—all are proofs of the sway of the law of gravity over the waters of the globe.

11. Drawn down in this way, by the action of gravity, all that portion of the rain which does not sink into the earth starts at once upon its course. It begins to move downwards, along the nearest slopes, and continues flowing until it can get no farther.

12. On the surface of the land there are hollows which arrest the course of part of the flowing water.

But these hollows, which form *lakes*, do not serve as permanent resting-places for the water. In most cases, this runs out at the lower end of the lake as fast as it runs in at the upper end.

13. The streams which flow from lakes, go on, as before, working their way to the sea-shore, by the most direct channel they can find. The course of all streams is a downward one; and the sea is a great basin into which the water from the land is continually flowing.

1. What makes the drops of rain fall to the ground?
2. What makes the water run along the road on the surface of the ground?
3. What is meant by the "force of gravity"?
4. Describe the formation of brooks and rivers.
5. Where does the water of rivers and lakes finally go?
6. How are lakes usually formed?

LESSON XXXIII.

THE FORMATION OF BROOKS AND RIVERS.

II.

1. If the surface of a country were a long, smooth ridge, like the roof of a house, the rain would quickly flow down, on each side, to the sea. But this is by no means the general character of the surface of the land. Mountains, hills, valleys, and lakes give it a very uneven and varied outline.

2. These greater inequalities strike the eye at once,

but even places which seem, at first, quite level, have some slope. There were little irregularities of surface on the road, which you did not notice until the rain found them out. Water is a most accurate measurer of the levels of a country, and always seeks the lowest level it can find.

3. If the rain should fall to the same depth over the entire surface of a country, would it flow off evenly? No; because the ground is uneven, and the rain runs off into the hollows. It is this unevenness which makes the rain collect into brooks, and the brooks into rivers. The brooks and rivers are thus the natural drains by which that part of the rain-fall not absorbed by the soil is conducted back to the sea.

4. When we consider the great amount of rain, and the enormous number of brooks in the higher parts of the country, it seems, at first, hardly possible for all these streams to reach the sea without ōverflowing the lower grounds. But when two streams unite they do not require a channel twice as broad as before.

5. Sometimes, indeed, the new stream is not so broad as either of the two which have formed it, but it becomes swifter and deeper. In this way thousands of streamlets, as they come together in their descent, may be made to take up less and less room. The surplus waters of a vast region may thus be borne into the sea by a single river-channel.

6. Let us return to the illustration of the roadway. Starting from the foot of the slope, you find the streamlets of rain getting smaller and smaller, and, when you get to the top, there are none at all. If you descend the road on the other side of the ridge, you will probably see other streamlets, coursing down-hill in the opposite direction. At the summit, the rain seems to divide, part flowing off to one side, and part to the other.

7. If you were to ascend some river, from the sea, you would find it becoming narrower, as you traced it inland. It would branch off, more and more, into tributary streams, and these, again, would subdivide into an almost endless number of little brooks.

8. Trace upward any of the branches which unite to form the main stream. You come, in the end, to the first beginnings of a little brook. Going a little farther, you reach the summit, down the other side of which all the streams are flowing in the opposite direction. The line which separates two sets of streams in this way, is called the *water-shed.*

9. It is only when rain is falling, or immediately after a heavy shower, that the rills are seen upon the road. When the rain ceases, the water begins to dry up, till, in a short time, the road becomes once more firm and dusty. But the brooks and rivers do not cease to flow, when the rain ceases to fall.

10. In the heat of summer, when, perhaps, there has been no rain for many days together, the rivers still roll on, smaller, usually, than they were in winter, but still with ample flow. What keeps them filled with water? If you remember what you have already been told about underground water, you will answer that rivers are fed by springs, as well as by rain.

11. Though the weather may be rainless, the springs continue to give out their supplies of water, and these keep the rivers flowing. But if great drought comes, many of the springs, particularly the shallow ones, cease to flow. The rivers fed by them, then shrink in size, or, perhaps, dry up altogether.

12. The great rivers of the globe, as the Mississippi, for instance, drain such vast territories, that any merely local rain or drought makes no sensible difference in their mass of water.

1. Why do streams flow?

2. What are lakes?

3. Why does the rain run off the surface of the land in brooks and rivers?

4. How are the many brooks of the higher parts of the country disposed of, as they descend towards the lower grounds?

5. What is a water-shed?

6. Why do rivers continue to flow in dry weather?

LESSON XXXIV.

THE WORK OF BROOKS AND RIVERS.

I.

1. Did you ever linger on a bridge, and watch the water flowing quietly in the stream beneath? It flows gently over its pebbly channel, not covering the whole of it, perhaps, but leaving banks of gravel, and pools of water, between which the clear current winds its way.

2. The river seems to be doing nothing but lazily carrying the surplus water of the land towards the sea. You might be surprised to be told that it has any work to do, and even now is doing it.

We have learned that the water of the river is largely derived from springs, and that all spring-water contains more or less mineral matter dissolved out of the rocks.

3. Every river, therefore, is carrying, not merely water, but large quantities of mineral matter, into the sea. This matter is not visible to the eye, and does not affect the color of the water. At all times of the year, as long as the water flows, some of the substance of the rocks is being carried away.

4. Let us watch the same river after a heavy rain. What a change the rain has made! Before, we could almost count the stones in the channel, the current

being so small and so clear. But look at it now! The water fills the channel, from bank to bank, and rolls along swiftly. It is no longer clear, but dull and dirty.

5. Take a little of this dirty-looking water home, and let it stand all night, in a glass. In the morning you will find that it is clear, and that a fine layer of mud has sunk to the bottom. It is mud, therefore, which discolors the swollen river. But where did this mud come from? Plainly, the heavy rain, and the flooded state of the stream, must have something to do with it.

6. You may stand for hours and watch the swollen, turbid torrent, rolling down its channel. During that time many tons of mud, sand, and gravel, must be swept past you. You see that, over and above the invisible mineral matter, which the water contains, the river is hurrying seaward with vast quantities of other, and visible materials.

7. It is clear that at least one great part of the work of rivers must be to transport the crumbled parts of the land, which are carried into them by springs, or by rain. Rivers also help in the general wearing-away of the surface of the land.

8. This may be readily seen by looking at the sides, or bed of a stream, when the water is low. Where the stream flows over hard rock, you find the rock

smoothed, and worn away. All the stones lying in the channel, are more or less rounded, and smoothed.

9. When these stones were first broken, by frost, or otherwise, from crags and cliffs, they were sharp-edged. You may satisfy yourself of this by looking at the fragments of stone lying at the foot of any precipice, or steep bank of rock. When they fell, or were washed into the river, they were rolled about, and rubbed together, until their sharp edges were ground away, and they came to have the smooth, rounded forms which we see in ordinary gravel.

10. While the stones are being ground down, they, at the same time, grind down the rocks which form the sides and bottom of the river channel over which they are pushed along. Now, it is clear that two results must follow from this ceaseless wear and tear of rocks and stones in the channel of a stream.

11. In the first place, a great deal of mud and sand must be produced. In the second place, the bed of the river must be ground down, so as to become deeper and wider. The sand and mud thus formed are added to the other similar materials washed into the streams, by rain, from the moldering surface of the land.

1. Whence is the water of rivers largely derived?
2. What does all spring-water contain?
3. Why is the water of a river discolored during a flood?

4. What is one great part of the work of rivers?

5. Where do the gravel and stones in the bed of a river come from?

6. Why are the stones smooth and rounded?

LESSON XXXV.

THE WORK OF BROOKS AND RIVERS.

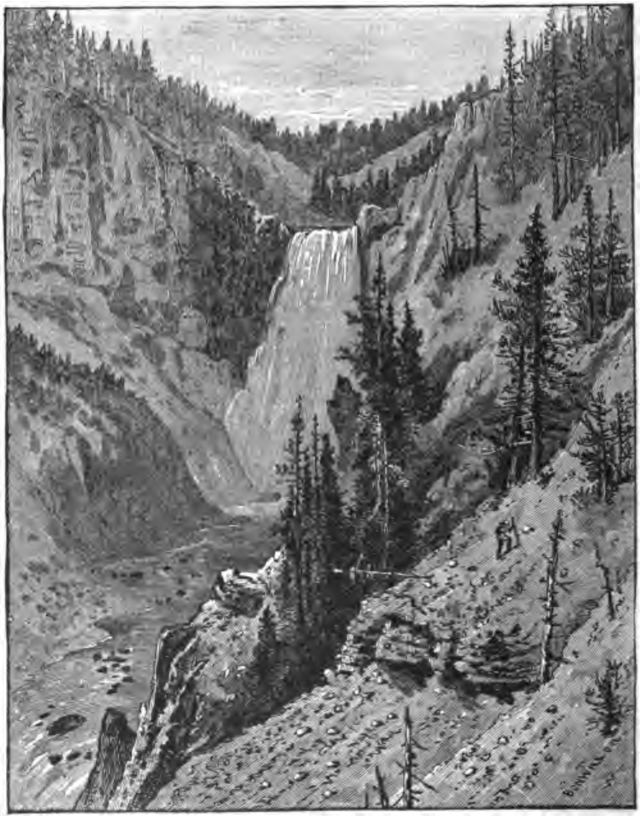
II.

1. All the mineral matter borne along by a river, whether brought down as mud, or held in solution, comes from one part of the land, to be carried to another part, or out to sea. It is, therefore, evident that some gaps and hollows must be left in the places from which this matter is taken. Let us see how these gaps are made.

2. Have you ever climbed up one of those small ravines in the hill-side, which have, generally, a little stream trickling through them? If so, you must have noticed the number of pebbles, large and small, lying in patches, here and there, in the stream. Many pieces of broken rock lie scattered along the sides of the ravine. As you climb, the path grows steeper, the rocks become rugged, and stick out in strange shapes.

3. An account of the formation of this ravine will tell us a great deal about the work of rivers. Once it was nothing more than a little furrow in the hill

side, down which the rain found its way in a thin thread-like stream.



4. By and by, as the stream carried down some of the earth, and the furrows grew deeper and wider; the sides began to crumble, as the sun dried up the rain which had soaked in. Then, in winter, after the

sides of the hill had been made moist with the autumn rains, frost came, and turned the water in the soil to ice, and so made the banks crumble still more.

5. The swollen stream, rushing down, caught the loose pieces of rock, and washed them into its bed. In time, this became a little valley. As the stream cut it deeper and deeper, there was room to clamber along the sides of it. Mosses began to cover the naked rock, and small trees rooted themselves along the banks.

6. At last the ravine became the beautiful little nook which you now see. It was cut out of the hill-side entirely by the water. Shall you not feel a fresh interest in all the little valleys, ravines, and gorges you meet with in the country, if you can picture them as being formed in this way, year by year?

7. All these picturesque features of the landscape were cut out of the hill-sides, and the solid rock, by the deepening and widening of the water-courses. There are many curious differences in them, which you can study for yourselves.

8. Some will be smooth, broad valleys. Here the rocks have been soft, and easily worn. Water, trickling down the sides of the first valley, has cut other channels, which have grown into smaller valleys running into the larger one. In other places there will

be narrow ravines. Here the rocks were hard, so that they did not wear away gradually, but broke off, and fell in blocks, leaving high cliffs on each side.

9. As you clamber up the ravine, perhaps you may come to a little water-fall. If you examine it closely you will see that the water, as it tumbled over the cliff, has worn its way back through the rock, like a saw cutting through a piece of wood.

10. A wonderful example of a water-fall is furnished by the Falls of Niagara. The River Niagara flows gently down from Lake Erie for about fifteen miles, and then, the slope becoming greater, hurries on to the Falls. These falls are one hundred and sixty-seven feet high, and twenty-seven hundred feet, or nearly half a mile, wide.

11. No less than six hundred and seventy thousand tons of water go over the Falls every minute, making magnificent clouds of spray. Sir Charles Lyell, the eminent geologist, when at Niagara, came to the conclusion that, taking one year with another, these falls cut back through the cliff at the rate of about one foot a year.

12. You can easily imagine that they would do this, when you think with what force the water must dash against the bottom of the Falls. In this way a deep chasm, the walls of which are, in some places, two hundred and fifty feet high, has been cut back from

Queenstown, for a distance of about six miles, to the place where the Falls now are.

13. This helps us, somewhat, to understand how very slowly and gradually water cuts its way through the rocks. If one foot a year is about the average of the waste of the rock at Niagara, it must have taken more than thirty-five thousand years for that channel of six miles to be made.

14. But this chasm, immense as it is, is small, compared with the cañons of the Colorado River. Cañon is a Spanish word, meaning a channel, or rocky gorge. These cañons are indeed so grand, that, if we had not seen, in other places, what water can do, we should never be able to believe that these gigantic chasms could have been cut out by it.

15. In north-western Arizona, for more than three hundred miles, the River Colorado has worn its way through limestone, sandstone, and granite, forming the Great Cañon of the Colorado, as it is called. It has cut down through these hard rocks until it has left walls from half-a-mile to a mile high, which stand straight up from the water's edge, through the entire length of the cañon.

16. Fancy yourself, for a moment, in a boat on this river, and looking up at these gigantic walls of rock, towering above you. A man half-way up them, even if he could get there, would appear so small you could

not see him without a telescope. Through the opening at the top, the sky would seem but a narrow streak of blue.

17. These huge chasms have not been made by any violent breaking apart of the rocks, in the convulsion of an earthquake. They have been gradually, silently, and steadily cut through by the river, which now glides quietly in the wider openings, or rushes foaming through the narrow gorges.

1. How are valleys, ravines, and gorges formed ?
2. Why are some valleys smooth and broad ?
3. Why are others narrow ?
4. How high are the Falls of Niagara ? How broad ?
5. How much water pours over them every minute ?
6. How fast do the Falls eat back the cliff ?
7. How much nearer Lake Ontario were they once ?
8. How long has it taken them to cut the deep chasm below the Falls ?
9. How high are the walls of this chasm ?
10. How high are the walls of the Great Cañon of Colorado ? How long is the Great Cañon ?

LESSON XXXVI.

THE WORK OF BROOKS AND RIVERS.

III.

1. You have seen why the rivers are muddy. Let us now inquire what becomes of all the mud, sand,

gravel, and blocks of stone, which they are continually carrying along with them. Look again at the channel of a river in summer. You see it covered with sheets of gravel in one place, beds of sand in another, while here and there a piece of hard rock stands up above the water.

2. If you note carefully some portion of the loose materials, you find it to be continually shifting. A patch of gravel, or sand, may remain for a time, but the little stones and grains of which it is composed, are always changing, as the water covers and moves them. They are constantly being pushed onward, and others, from higher up the stream, come down to take their place.

3. It is not on the beds of the rivers, then, that the material worn away from the surface of the land can find any lasting rest, and yet the rivers do get rid of much of this material as they roll along. You have, perhaps, noticed that a river is often bordered with a strip of flat plain, the surface of which is only a few feet above the level of the water.

4. Most of our rivers have such margins. Indeed, they seem to wind through a long, level, meadow-like plain. Now, this plain is really made up from the finer particles of the decomposed rocks which the river has scattered here.

During floods, the river, swollen and muddy, rises

above its banks, and spreads over the low ground on either side.

5. The overflowing water moves more slowly over the flats. As its current is thus checked, it cannot hold so much mud and sand, but allows some of these materials to settle down to the botton. In this way the overflowed tracts get a coating of soil laid over them by the river, and, when the waters retire, this coating adds a little to the height of the plain.

6. The same thing takes place year after year. By degrees the plain gets raised so high that the river, which all this while is also deepening its channel, cannot overflow it, even at the highest floods. In course of time the river, as it winds from side to side, cuts away portions of the plain, and forms a newer one at a lower level. Thus a series of terraces, rising step by step above the river, may be gradually made.

7. The laying down of its sand and mud by a river, to form one or more such terraces, is, after all, only a temporary disposal of these materials. They are still liable to be carried away, and, in truth, they are carried off continually, as the river eats away its banks.

8. When the current of a river is checked, as it enters the ocean or a lake, the feebler flow of the water allows the sand and mud to sink to the bottom. By degrees some portions of the bottom come, in this way, to be filled up to the surface of the river, and

wide, flat, marshy tracts are formed on either side of the main stream.

9. During floods these tracts are overflowed with muddy water, in the same way as the valley plains just described. Successive coatings of mud or sand are laid down on them, until they slowly rise above the ordinary level of the river, which winds about among them in endless, branching streams.

10. Vegetation springs up on these flat, swampy lands; animals find food and shelter there; and thus a new tract of land is built up by the work of the river. These flat, river-formed tracts are called *Deltas*, because the one best known to the ancients, that of the river Nile, had the shape of the Greek letter, delta, Δ.

11. This is the usual shape taken by accumulations at the mouths of rivers. Some of them, as the delta of the Mississippi, for example, are of enormous size. Vast as some deltas are, however, they do not show all the materials which have been worn away and carried down by the river. Much is borne far out beyond them, and deposited on the bottom of the sea, for the sea is the great basin into which the waste of the land is continually borne.

1. How are the plains, through which rivers run, formed?

2. Why does a river deposit a coating of soil on overflowed lands?

3. How are terraces formed?
4. How are deltas formed? Why are they so named?
5. What becomes of the waste of the land?

LESSON XXXVII.

HOW THE SURFACE OF THE EARTH CRUMBLES AWAY.

I.

1. It may seem strange to you to be told that the surface of the earth is continually crumbling away. When it is possible to examine a stone building that has stood for a few hundred years, as may be done in many countries of the old world, one will see that the smoothly dressed face, which its walls received from the mason, is usually gone.

2. The stones are worn into grooves and furrows. The carvings over window and doorway are so wasted that it is sometimes difficult to make out what they were intended to represent. Wherever old masonry is found, this time-eaten appearance is so familiar, that one always looks for it in an old building. If it is not found, he at once doubts whether the building can really be old.

3. In old cemeteries in the country, you see tombstones more and more moldered the older they are. Sometimes the inscriptions, dating from two or three

generations back, are so nearly wasted away that you cannot now tell whose names and virtues they were intended to commemorate.

4. In the case of buildings, and other works of human construction, the decay may be noted and measured. The stones, rough and worn as they may be now, left the hand of the mason with smoothly dressed surfaces. But the decay is not confined to human creations. On the contrary, it goes on over the whole face of the earth.

5. Look at the cliffs and ravines, the crags and water-courses in your neighborhood. At the foot of each cliff you will probably find the ground cumbered with blocks, and heaps of smaller pieces, which have fallen from the rocks above. You may even find a fresh scar, where a piece has been recently broken off, and added to the pile of fragments below.

6. Wherever rocks are exposed to the air, they are liable to waste away. This change is called *weathering*. Let us see how it is brought about. To do this, we must return, for a moment, to the action of carbonic acid, which has been already described.

The rain, you remember, abstracts a little carbonic acid from the air, and still more from the soil.

7. When it sinks into the earth, it is enabled, by means of the carbonic acid, to eat away some parts of the rocks beneath the soil. The rain that rests

upon, or flows over, the surface of the ground, does the same work. It dissolves out, little by little, such portions of the rocks as it can remove.

8. In the case of some rocks, as limestone, the whole, or almost the whole, of the substance of the rock, is carried away in solution. In other kinds, the portion dissolved is the cementing material, by which the mass of the rock was held together. When this is taken away, the rock crumbles into mere earth or sand, and this is readily washed away by the rain. Hence, one cause of the moldering of stone is the action of carbonic acid taken up by the rain.

9. In the second place, the oxygen of the air helps to decompose the rocks. When a piece of iron has been exposed for a time to the weather, it rusts. This rust is a compound substance, formed by the union of oxygen with iron. It continues to be formed as long as any of the unrusted iron remains. As each layer of rust is washed off, a fresh surface of iron is laid open to the attack of the oxygen.

10. What happens to the iron, happens also, though not so quickly, nor so strongly, to many rocks. They, too, rust by absorbing oxygen. A crust of corroded or rusted rock gathers on their surface, and when this is washed off by the rain, a fresh layer of rock is reached by the active and ever-present oxygen.

11. In the third place, the surface of many parts of

the earth is made to crumble away by the action of frost. You know that sometimes, in winter, when the cold becomes very keen, the water-pipes burst, and pitchers, filled with water, are cracked from top to bottom. The reason of this lies in the fact that water expands in freezing.

12. Ice requires more space than the water would need, if it remained fluid. When ice forms within a confined space, it exerts a great pressure on the sides of the vessel or cavity which contains it. If these sides are not strong enough to bear the strain to which they are put, they must yield, and therefore they crack.

13. You have learned how easily rain finds its way through soil. Even the hardest rocks are more or less porous, and take in some water. Hence, when winter comes, the ground is full of moisture. This moisture is found, not in the soil alone, but in the rocks, also, and, as frost sets in, it freezes.

14. Now, precisely the same kind of action takes place with each particle of water in the rock, as in the case of the burst water-pipe or the cracked pitcher. It does not matter whether the water is collected into some hole or crevice, or is scattered between the grains of the rocks and the soil. When it freezes it expands, and, in so doing, tries to push apart the walls between which it is confined.

1. How do you account for the fragments of stone found at the foot of cliffs?
2. What are rocks liable to when exposed to the weather?
3. What is this change called?
4. How does rain act on limestone?
5. How does it act on some harder rocks?
6. What is iron-rust?
7. How do the rocks rust?
8. Show how frost acts on the rocks?

LESSON XXXVIII.

HOW THE SURFACE OF THE EARTH CRUMBLES AWAY.

II.

1. If you walk along a road, just after a frost, you see that the surface has become a layer of fine mud. The frost has separated the grains of sand and clay, as if they had been broken up in a mortar. In this way the frost proves of great service to the farmer, by breaking up the soil, and loosening it for the roots and fibres of plants.

2. When a surface of rock has been well soaked with rain, and is then exposed to frost, the grains of rock undergo the same kind of pressure from the freezing of the water in the pores between them. They are not so loose and open, however, as those of

the soil are. Hence they withstand the action of the frost much better.

3. Of course, the most porous rocks, or those which hold most water, are most easily affected by this action. Porous rocks, such as sandstone, are often liable to rapid decay from frost. The stone has crust after crust peeled off from it, as its grains are loosened from each other, and washed away by the rain.

4. Again, water freezes, not only between the grains, but in the numerous crevices, or joints, as they are called, by which rocks are traversed or crossed. You may have noticed, on the face of a cliff or in a quarry, that the rock is cut through by lines running more or less in an upright direction. These joints have already been shown to be passages made by the water in its descent from the surface.

5. Only a very little water may be admitted, at one time, into a joint. But by degrees the joint widens a little, and allows more water to enter. Every time the water freezes it tries hard to force apart the two sides of the joint. After many winters it is at last able to separate them a little.

6. Then, more water enters and more force is exerted in freezing. At last the block of stone traversed by the joint is completely split up. When this takes place along the face of a cliff, one of the loosened

parts may fall off and roll down to the bottom of the precipice. In countries exposed to severe winters, the waste caused by frosts, along lines of steep cliffs, is often enormous.

7. In addition to carbonic acid, oxygen and frost, there are other influences at work by which the surface of the earth is made to crumble. For instance, during the day the rocks may be highly heated by the sun, and, during the night, rapidly cooled by radiation. The alternate expansion and contraction, brought about by heating and cooling, loosen the particles of the rock, causing them to crumble away.

8. Thus, you see, from a variety of causes, the solid rocks of the earth are liable to continual decay and removal. The hardest stone, as well as the softest, must yield in the end, and molder down. They do not all decay at the same rate. Cliffs formed of one kind of stone will crumble down faster than others, and will do so in a different way.

9. If, then, it be true, as it is, that a general wasting of the surface of the land goes on, you may naturally ask why this should be. The world seems so fair and beautiful, you cannot realize that there should be so much, and such constant, decay of its surface. You may be even inclined at first to consider the decay a misfortune hardly to be explained.

10. Instead of being a misfortune, this moldering of

the surface is, in reality, necessary to make the earth fit to be the dwelling-place of plants and animals. To it we owe our valleys and ravines, and all the pleasing outlines of crag and hill. Out of the crumbled stones all soil is made, and on the formation and renewal of the soil we depend for our daily food.

1. How does the frost act on the soil?

2. How is this action of service to the farmer?

3. What kind of rocks are most easily affected by the action of frost?

4. What name is given to the cracks by which rocks are traversed?

5. What is the effect of the freezing of water in these cracks?

6. Do you think that the action of frost, on rocks in this country, is considerable? Why?

7. Why is the moldering of the surface of the earth necessary?

8. What do we owe to it?

LESSON XXXIX.

HOW SOIL IS MADE.

1. Take up a handful of soil from the field or garden, and look at it attentively. What is it made of? You see little pieces of crumbling stone, particles of sand and clay, perhaps a few vegetable fibres. The whole soil has a dark color, from the decayed remains of plants and animals scattered through it

How have these different materials been brought together?

2. In speaking of the general moldering of the surface of the earth, we applied the words "decay" and "waste" to this process. But in reality, although the rocks may crumble away, year by year, there is no actual loss of matter. The substance of the rock may waste away, but it is not destroyed. It only changes its condition and its form. What, then, becomes of all this material which is continually being worn from the rocks around us?

3. Every drop of rain which falls upon the land, helps to alter the surface. You have followed the chemical action of rain as it dissolves parts of rocks. It is by the constant repetition of this work, drop after drop, and shower after shower, for years together, that the rocks become so wasted and worn.

But the rain has also a *mechanical* action.

4. Watch what happens when the first pattering drops of a shower begin to fall upon a smooth surface of sand, such as that of a beach. Each drop makes a little dent, or impression. It thus forces aside the grains of sand. On sloping ground, where the drops can run together, and flow downward, they are able to push or carry the grains along. This is called a *mechanical* action. The actual solution of the particles, as you dissolve sugar or salt, is a *chemical* action.

5. Each drop of rain may act in one, or both, of these ways. Now you can readily see how it is that rain can do so much in the destruction of rocks. It not only dissolves out some parts of them, and leaves a crumbling crust on the surface, but it washes away this crust, and thereby exposes a fresh surface to decay.

6. There is, in this way, a continual pushing along of powdered stone over the earth's surface. Part of this material accumulates in hollows, and on sloping or level ground; part is swept into the rivers, and carried away into the sea.

It is this crumbled stone, mingled with the remains of plants and animals, of which all our soils are made.

7. Soils differ, therefore, according to the kind of rock out of which they have been formed. Sandstone, for instance, will give rise to a sandy soil; limestone, to a limy soil; clay-rocks, to a clayey soil. Every species of rock has produced its own kind of soil, by gradual weathering, under the action of the atmosphere, the rain, and the other influences that have been mentioned.

8. Were it not for this crumbling of the rocks into soil, the land would not be covered with verdure as it is, and the rocks all over the valleys and plains would not be covered with fertile soil. Only where, as in steep banks and cliffs, they rise too abruptly to

let their crumpled remains gather upon them, do they stand up naked and without verdure.

9. As the moldering of the surface of the land is always going on, there is a constant formation of soil. Indeed, if this were not the case,—if, after a layer of soil had been formed upon the ground, it were to remain there, unmoved and unrenewed, the plants would in time take out of it all the earthy materials they could use. It would then be left in a barren, or exhausted state.

10. But some of it is being slowly carried away by rain. Fresh particles from moldering rocks are washed over it by succeeding showers, while the rock or sub-soil underneath is all the while decaying into soil. The loose stones, too, are continually crumbling down, and making new earth, and thus, day by day, the soil is slowly renewed.

11. Plants help to form and renew the soil. They send their roots among the grains and joints of the stones and loosen them. Their decaying fibres supply most of the carbonic acid by which these stones are attacked, and furnish, also, most of the organic matter in the soil.

12. When we think about this decay and renewal of the soil, we see that, in reality, the whole surface of the land may be looked upon as traveling downward, toward the sea. The particles worn from the

sides and crests of the high mountains may take hundreds, or even thousands of years on the journey.

13. They may lie for a long time on the slopes of the hills. Then they may be swept down and form part of the soil of the valleys. After resting here a while they may be again borne away, and laid down on the bed or bank of a river. Thus, after many years, and many halts by the way, they at last reach the sea.

14. In order to form some idea of the extent to which the surface of the land is cleared of its loose soil by rain, you should notice what takes place after every heavy shower. Each little rivulet and brook becomes muddy and discolored from the quantity of soil, that is, decayed rock, which has been washed into it from the adjacent slopes.

15. The mud which darkens the water is the finer particles of the decomposed rocks. The coarser parts are moving along at the bottom of the stream. When you watch these streamlets at their work, you must remember that what they are doing now they have been doing for ages past. You will then understand how greatly the surface of a country may come to be changed by the action of what, at first, seems so insignificant a thing as rain.

1. What gives to soil its dark color?
2. In how many ways may a drop of rain act on rocks?

3. What are these called?
4. Of what does soil consist?
5. Why do soils differ?
6. If the soil were not constantly renewed, what would be its condition?
7. How do plants help to renew the soil?
8. What is mud?

LESSON XL.

SNOW-FIELDS AND GLACIERS.

I.

1. Having now followed the course of the water that falls on the land as rain, we come to the course taken by snow. In this country snow is seen only during the winter. But in those parts of the earth where the mountains are very high, their peaks gleam white with unmelted snow all the year.

2. Hardly anything in the world impresses one so much as the silence and grandeur of these high, snowy regions. When we look at them from the valleys, these mountains look so vast and distant, so white and pure, yet showing so wonderfully all the colors which glow in the sky, at noon or evening, that they seem to be rather parts of the sky above than of the solid earth on which we are.

3. It is when you climb up among them that their

wonderful stateliness comes full before you. Peaks and pinnacles of the most dazzling whiteness, streaked with lines of purple, glisten against the blue of the sky. Points of dark rock project through the

white mantle that throws its heavy folds far and wide over ridge or slope.

4. There is deep silence over this high, frozen region. Now and then a gust of wind brings up, from the far distance, the sound of some remote water-fall, or the dash of a mountain torrent. At times there is a dull

roar, as of distant thunder, when some mass of ice or snow, loosened from the rest, shoots down the side and over a precipice. But these noises only make the silence deeper when they have passed away.

5. Let us see why it is that perpetual snow is found in such regions, and what part this snow plays in the work of grinding down rocks and plowing out valleys.

In the far north, and the far south, around those two opposite points of the globe, called the *poles*, the climate is extremely cold. Dreary expanses of ice and snow lie all around. Sea and land are frozen, and the heat of summer is never great enough to melt all the snow and ice.

6. Between these two polar tracts of cold, there are, in many places, mountains lofty enough to reach up into the higher portions of the atmosphere, which are extremely cold. The temperature, upon these mountain tops, is usually below the freezing point, and the vapor condensed from the air falls upon them, not as rain, but as snow. Their summits and upper heights are thus covered with perpetual snow.

7. In such high, mountainous regions, the heat of summer always melts the snow from the lower hills, though it leaves the higher parts still covered. From year to year it is noticed that there is a line, or limit, below which the snow melts, and above which it

remains. This line is called the *snow-line*, or the limit of perpetual snow.

8. Its height varies in different parts of the world. It is highest in the warm regions on either side of the equator. Here it reaches from fifteen to twenty thousand feet, or from three to four miles above the sea. In the cold, polar tracts, on the other hand, it approaches the sea-level.

9. In other words, in the polar tracts, the climate is so cold that perpetual snow is found even close to the sea. But the equatorial regions are so warm that you must climb many thousand feet before you can reach the cold layers of the air, where snow can remain all the year.

1. In what part of the globe is the heat of summer never great enough to melt all the snow and ice ?
2. Where else is perpetual snow found ?
3. What is the snow-line ?
4. Where is the snow-line highest ? Where is it lowest ?
5. How high is it in the equatorial regions ?

LESSON XLI.

SNOW-FIELDS AND GLACIERS.

II.

1. When you watch a snow storm, you see how, at first, a few small flakes show themselves, drifting slowly through the air. They soon increase in num-

ber and in size; the ground begins to grow white, and, as hours go on, the whole country becomes covered with a white carpet, perhaps six inches, or more, in thickness.

2. One striking difference between rain and snow will be noticed. If rain had been falling for the same

length of time, the roads and fields would still be visible. The drops of rain, instead of remaining where they fell, would have sunk into the soil, or have flowed off into the nearest brook. But each snowflake lies where it falls, unless it happens to be caught up and driven on by the wind to some other spot where it can finally rest.

3. Rain disappears from the ground as soon as it can; snow lies quietly on the ground as long as it can. This marked difference between rain and snow gives rise to some equally strong differences in the further

action of these two kinds of moisture. We have followed the course of the rain; let us now try to find out what becomes of the snow.

4. In such a country as ours, you can answer this question without much difficulty. The snow that falls in winter remains on the ground as long as the air is not warm enough to melt it. Evaporation, indeed, goes on from the surface of snow as well as from water. A layer of snow would, in the end, disappear by being absorbed into the air as vapor, even though none of it were melted into running water.

5. But it is by what we call a *thaw* that our snow mainly disappears,—that is, a rise in the temperature, and a consequent melting of the snow. When the snow melts, it sinks into the soil, or flows off into brooks, in the same way as rain. We need not follow its after course, for it is the same as that of the rain.

6. In the regions of perpetual snow, the heat of summer cannot melt all the snow that falls there during the year. What other way of escape, then, does the frozen moisture find? That it must have some means of taking itself off the mountains is evident after a moment's thought.

7. If it had not, it must accumulate there from year to year, and from century to century. Every fresh fall of snow would add a little to the height of the mountains. These would grow into vast masses of

snow, reaching far up into the sky and spreading out on all sides. By degrees they would bury the low-lands around.

But nothing of this kind takes place.

8. These solemn, snowy heights wear the same unchanged look year after year. There is no hiding of their well-known features under a constantly increasing depth of snow. The surplus rain-fall flows off by means of rivers. The surplus snow-fall above the snow-line has a similar kind of drainage.

It flows off by means of *glaciers*.

9. When a considerable depth of snow has accumulated, the weight of the upper layers presses what lies below into a firm mass. The surface of the ground is seldom anywhere quite flat; usually it slopes in some direction.

10. Among the high mountains the slopes are often very steep. As the snow gathers to a considerable depth on the sloping ground, there comes a time when the force of gravity overcomes the tendency of the pressed snow to remain where it is, and it begins to slide slowly down the slope.

11. From one slope it passes on, downward, to the next. In its descent it is continually being joined by snow sliding from other slopes. Finally all unite in one large mass, which creeps slowly down some valley to a point where it melts. This creeping

mass is the glacier. It really drains the snow-fields of their excess of snow, as much as a river drains its basin of the excess of water.

1. How does the rain disappear from the ground?
2. How does most of our snow disappear?
3. Name another way in which snow disappears.
4. When the snow melts what becomes of the water?
5. What becomes of the surplus rain-fall?
6. What becomes of the most of the surplus snow-fall above the snow-line?
7. What makes the snow slide down the sides of a mountain?

LESSON XLII.

GLACIERS.

1. The glacier which comes out of the snow-fields is, itself, made not of snow, but of ice. The snow, as it slides downward, is pressed together into ice. Each snow-flake is made up of little crystals of ice. A mass of snow is thus only a mass of minute crystals of ice, with air between them.

2. Hence, when snow is pressed together, the air is forced out, and the separated crystals of ice freeze together into a solid mass. You know that you can make a snow-ball very hard by squeezing it firmly between the hands. The more tightly you press it,

the harder it gets. You are doing to it just what happens when a glacier is formed out of the snow.

3. You are pressing out the air, and allowing the little particles of ice to freeze to one another and form a compact mass. But you cannot squeeze nearly all the air out. Consequently the ball, after all your efforts, is still white from the imprisoned air. Among the snow-fields, however, the pressure is immensely great. More and more of the air is forced out, until, at last, the snow becomes clear, transparent ice.

4. A glacier, then, is a river of ice, coming down from the snow-fields. It descends, sometimes, a long way below the snow-line, creeping very slowly down along the valley, which it covers from side to side. During the day, in summer, its surface is melting. Streams of water are flowing along the ice, though, when night comes, these freeze again.

5. At last, the glacier reaches some point in the valley where the warmth of the air melts the ice as fast as it advances, and it can go no farther. So the glacier ends, and, from its melting end, streams of muddy water unite in a river, which carries, still farther down, the drainage of the snow-fields above.

6. A river wears down the sides and bottom of its channel. It thus digs out a bed for itself in even the hardest rock, as well as in the softest soil. It sweeps

down, too, a vast quantity of mud, sand and stones from the land to the sea. A glacier performs the same kind of work, but in a very different way.

7. When stones fall into a river, they sink to the bottom, and are pushed along there by the current. When mud is washed into a stream it remains suspended in the water, and is thus carried along. But the ice of a glacier is a solid substance. Stones and mud which fall upon its surface remain there, and are borne onward with the whole mass of the moving glacier.

8. Still the ice often gets broken into deep cracks, and opens into yawning clefts, or *crevasses*. These sometimes receive a great deal of the earth and stones let loose by frost, or otherwise, from the sides of the valley.

9. In this way loose materials fall to the bottom of the ice, and reach the solid floor of the valley, down which the ice is moving. Similar materials fall between the edge of the glacier and the sides of the valley. We shall see how the glacier makes use of these in the work of cutting out its channel.

10. The stones and grains of sand which become jammed between the ice, and the rock over which it is moving, are made to score and scratch this rock. They form a kind of coarse polishing powder, by means of which the glacier is continually scouring

away the bottom and sides of its channel. You can now see the reason why the river that flows from the end of a glacier is always muddy.

11. The bottom of the glacier is crowded with stones held firmly by the ice, and these are scraping and wearing down the rock underneath. A great deal of fine mud is thus produced. Borne along by streams of water, flowing in channels under the glacier, it flows out at the end in the discolored torrents which there sweep from beneath the ice.

12. But a glacier has other work to do besides plowing out for itself a channel through the mountains. Its surface does not long retain the purity of the snow from which it was formed. Enormous quantities of earth, stones and rock tumble upon it from the cliffs on either side. These form long lines of rubbish upon the glacier, which are called *moraines.*

13. In this way blocks of rock as large as a house may be carried for many miles, and dropped where the ice melts. Thousands of tons of loose stones and mud are every year brought on the ice, from the far mountain heights down into the valleys through which the glacier winds to meet its doom from the sunbeams.

1. How does the snow of which a glacier is formed become ice?

2. What is a glacier?

3. When does a glacier melt away?

4. Why is the stream of water flowing from the end of a glacier muddy?

5. How does a glacier transport rocks?

LESSON XLIII.

GLACIERS AND ICEBERGS.

1. The largest glaciers in the world are those of the polar regions. In Greenland and in Norway there are enormous glaciers. They are found in Europe, among the Alps, in Asia, among the Himalayas, and in Iceland and Spitzbergen. Even in Switzerland, there are some very large ones. Such rivers as the Rhone and Rhine, which owe their origin to glaciers in the Alps, are thick with matter brought down from the mountains.

2. The Rhone leaves its mud in Lake Geneva, and flows out at the other end quite clear and pure. A mile and a half of land, a sort of delta, has been formed at the head of the lake, within the last two thousand years, by the mud thus brought down from the Alps.

3. Glaciers move very slowly,—they move also very singularly. The center of the great glacier moves more rapidly than the outside. The center moves twenty to twenty-seven inches, and the outside thirteen to nineteen inches, in twenty-four hours during the summer

and autumn. *How* they move, we cannot stop to inquire now. If you will take a slab of thin ice, and support it upon its two ends, you can prove to yourself that ice will bend.

4. In a few hours you will find that its own weight has drawn it down in the center so as to form a curve. This may help you to understand how glaciers can adapt themselves to the windings of the valley, creeping slowly onwards until they come down to a point where the air is warm enough to melt them. Then the ice flows away in a stream of muddy water.

5. North Greenland lies buried under one great glacier, which creeps down the valleys and away out into the sea. When a glacier advances into the sea, parts of it break off and float away as *icebergs*. So enormous are the glaciers in these cold regions, that the icebergs broken from them often rise several hundred feet above the waves that beat against their sides.

6. And yet, in all such cases, about eight times as much of the ice is immersed under water, as the portion, large as it may be, which appears above. You can realize how this comes to be so, if you put a piece of ice in a tumbler of water, and notice how much of it rises out of the water.

7. Sunk deep in the sea, the icebergs float to and fro until they melt, sometimes many hundreds of miles away from the glaciers from which they have parted.

You will come to learn, by and by, that, once, ages ago, there were glaciers in this country.

8. You may be able to see, with your own eyes, rocks which have been scored and scratched by the ice, and large masses of rock, and piles of loose stones which the ice carried upon its surface.

So that, in learning about glaciers, you are not merely learning what takes place in other lands, but you are gaining knowledge you may some time be able to make good use of in our own country.

1. Where are the largest glaciers found?
2. Where are glaciers found in Europe?
3. How fast do glaciers move?
4. Do they move as fast at the sides as in the center? Why?
5. Do they move as fast in winter as in summer? Why?
6. What is an iceberg?
7. What part of an iceberg rises out of water?
8. What becomes of icebergs?

LESSON XLIV.

THE SEA.

1. Since we live on land, and are familiar with the various shapes which the surface of the land assumes, —plains, valleys, hills, mountains, and so on—we are apt to think that the land is the greater part of the

globe. Many of us who live in inland parts of the country, have never been off the land, nor seen any larger sheet of water than a river or pond, or perhaps a large lake.

2. And yet, if you were to travel far enough in any direction, you would at last come to the edge of the land, and find a vast expanse of water before you.

It has been ascertained that, in reality, the water covers three times as much of the earth's surface as the land does.

3. We could not discover that fact by what we can see from any part of this country, or, indeed, of any country. It is because men have sailed round the world, and have crossed it in many directions, that the relative proportion of land and water has come to be known.

4. Take a school globe, and turn it slowly round on its axis. You see, at a glance, how much larger the surface of the water is than the surface of the land. You may also notice several other interesting things about the distribution of land and water.

5. In the first place, you will find that the water is all connected together, in one great mass, which we call the *sea*. The land, on the other hand, is much broken up by the way the sea runs into it. Some parts are entirely cut off from the larger portions, and these we call *islands*.

6. In the second place, you cannot fail to notice how much more land lies on the north, than on the south side of the equator. Thirdly, you will see that, by the way in which the masses of land are placed, parts of the sea are, to some extent, separated from one another. These masses of land are called *continents*, and the wide sheets of water between them are termed *oceans*.

7. Picture to yourselves that the surface of the solid part of the earth is uneven, some parts rising into broad elevations and ridges; others sinking into

wide hollows and basins. Now, into these hollows the sea has been gathered. Only those high portions which rise above the level of the sea form the land.

8. In the preceding lessons, mention has often been made of the Sea. You have been told that the moisture of the air comes, in great part, from the sea. The rivers from the land are continually flowing into the same great reservoir. The sea is likewise the great basin into which all the soil that is worn from the surface of the land is being carried. We must now look a little more closely at some of the most important features of the sea.

1. How have the relative amount of land and water on the surface of the globe been determined?
2. What part is land?
3. How is the land part broken up?
4. How are parts of the sea separated from one another?
5. By what names are the land masses known?

LESSON XLV.

WHY THE SEA IS SALT.

1. When you come to examine the water of the sea you find that it differs from the water with which you are familiar on the land, inasmuch as it is salt. It contains something which you do not notice in rain,

or in spring or river water. To distinguish the water of springs, rivers, and lakes from that of the sea, it is sometimes called *fresh* water.

2. If you take a drop of clear spring water, and allow it to evaporate from a piece of glass, you will find no trace left behind. The water of springs, however, always contains more or less mineral matter dissolved in it. As these substances cannot rise in vapor, they are left behind when the water evaporates.

3. But the quantity of them in a single drop of water is so minute that, when the drop dries up, it leaves no perceptible trace. Take, now, a drop of sea-water, and allow it to evaporate. You find a little white film left behind. If you place that film under a microscope, you will see that it consists of delicate crystals of common salt.

4. There are some other things, besides salt, in sea-water. But the salt is the most abundant, and we need not inquire about the others at present. Where did all this salt, and other mineral matter in the sea, come from? The salt of the sea is all derived from the waste of the rocks.

5. It has already been pointed out how, both underground and on the surface of the land, water is always dissolving out of the rocks various mineral substances. Of these salt is one. Hence the water of

springs and rivers contains salt, and this is borne away into the sea.

6. From all over the world there must be a vast quantity of salt carried into the sea every year, by the rivers that flow into it. But the amount of salt contained in *fresh* water is so small that no trace of it appears, except on chemical analysis. Every day millions of tons of water are passing from the ocean into vapor of water in the atmosphere. The sea gives off again, by evaporation, as much water as it receives from rain, and from the rivers.

7. Streams are every day carrying fresh supplies of salt into the sea, and the salt remains there. The waters of the sea must consequently be getting salter by degrees. Such is the case, but the process is an extremely slow one, and we could not discover its results by observation alone.

1. How does the water of the sea differ from that on the land?

2. What is fresh water?

3. Is there any salt in fresh water?

4. Why do we not taste it?

5. Whence is the salt of the sea derived?

6. How do you know that the water of the sea is becoming more salt?

LESSON XLVI.

THE WAVES OF THE SEA.

1. If you stand upon the shore, and watch for a little time the surface of the sea, you will notice that it is very restless. Even on the calmest summer day, a slight ripple, or a gentle heaving motion, will be seen. At other times, little wavelets curl towards the land, and break in long lines upon the beach.

2. When storms arise, you may watch how the water has been rolled up into huge waves, which, crested with spray, come in, tossing and foaming, to break upon the shores.

There are other movements of the sea, but, for the present, it will be enough if we learn something about the waves.

3. You can illustrate their formation in a very simple way. If you take a basin of water, and blow upon the water, at one side, you throw its surface into little ripples. Starting from the point where your breath first strikes the water, these roll onward until they break in little wavelets upon the opposite side of the basin.

4. The waves of the sea are formed in the same way. The wind acts upon the water of the sea just as your breath does on that in the basin. The disturb-

ance of the smoothness of the sea is due to movements of the air. Striking the surface, it throws the water into ripples, and as it continues to blow along the surface it gives these additional force, until, driven on by a furious gale, they grow into huge billows.

5. The restlessness of the surface of the sea is thus a reflection of the restlessness of the air. It is the constant moving to and fro of currents of air, either gentle or violent, which roughens the sea with waves.

6. When the air is calm above, the sea sleeps peacefully below. When the sky darkens and a tempest breaks forth, the sea is lashed into furious waves, which roll in, and break with enormous force, upon the shore.

7. You have heard, perhaps you have even seen, something of the destruction which is wrought by the waves of the sea. So that, besides all the waste which the surface of the land undergoes from rain, and frost, and rivers, there is another form of destruction going on along the coast-line.

8. By the continual up and down movement of the water, the sand and stones near the shore are kept grinding against one another. The stones become smaller and smaller, until they are worn into mere sand. The sand, growing finer and finer, is at last swept away out to sea and laid down on the bottom.

9. The place of the stones thus ground away is sup-

plied by others, swept up by the waves or battered from the ledges.

On rocky shores the different stages in the wearing away of the land by the sea can, sometimes, be strikingly seen. The waves in a storm dash against the cliffs, and even break off pieces of rock which fall on the shore below.

10. It is, however, the stones, and sand, and fragments of rock lying at their feet which are most active in wearing the cliffs away. In a heavy storm the waves catch up these loose stones, hurl them forward, and batter the rocks with them.

11. At high tide, in such a storm, these stones are thrown against the foot of the cliff. Each blow does something towards breaking away part of the rock. At last, after many storms, the cliff is undermined, and large pieces fall down. These pieces help to batter down the remaining rock, and are, in their turn, ground down to pebbles.

12. It is said that, in a storm, the waves have been known to beat against the rocks with as much force as if a weight of three tons were dashed upon every square inch of their surface. Rocks weighing two tons have been thrown entirely over the ledge on which a lighthouse was built.

13. Think what force there must be in waves which can lift up such a rock and hurl it many feet before

them. It is such a force as this, remember, that is beating upon our sea-coasts year after year, and wearing away the land.

1. What causes waves?
2. To what is the restlessness of the sea due?
3. Where do the stones in the sea, near the shore, come from?
4. What becomes of them?
5. What becomes of the sand?
6. What wears away the cliffs on the sea-shore?
7. With what force have the waves been known to beat against the cliffs?
8. How heavy rocks have been thrown up by them?

LESSON XLVII.

THE BOTTOM OF THE SEA.

I.

1. So far as we know, the bottom of the sea is very much like the surface of the land. It has heights and hollows, lines of valleys and ranges of hills, broad plains and mountain peaks and chains.

2. We cannot see down to the bottom when the water is very deep, but we can let down a long line with a weight tied to the end of it, and find out how deep the water is. This measuring of the depth of the water is called *sounding*, and the weight at the end of the line, a *sounding-lead*.

3. Soundings have been made over many parts of the sea, and something is now known about the bottom, though much still remains to be discovered. The Atlantic Ocean has been most explored in this way. Between the Azores and the Bermudas, a sounding of seven miles and a half has been obtained.

4. If you could lift up the Himalaya Mountains, which are the highest on the globe, reaching a height of twenty-nine thousand feet above the sea, and set them down in the deepest part of the Atlantic, they would sink entirely out of sight. More than that, their tops would actually be about two miles below the surface.

5. A great part of the wide sea must be one or two miles deep. But it is not all so deep as that, for, even in mid-ocean, some parts of its bottom rise up to the surface and form islands. As a rule, it deepens in the tracts farthest from land, and becomes shallow towards the land. Hence, those parts of the sea which run in among islands and promontories are, for the most part, comparatively shallow.

6. You may readily enough understand how it is that soundings are made. You can see, too, how difficult it must be to use a sounding-line several miles long. Yet men are able, not only to measure the depth of the water, but, by means of the instrument called a *dredge*, to bring up bucketfuls of whatever

may be lying on the sea-floor, from even the deepest parts of the ocean.

7. In this way, during the last few years, a great deal of additional knowledge has been gathered as to the nature of the sea-floor, and the kinds of plants and animals that live there.

If you put together some of the facts with which we have been dealing in the foregoing lessons, you may for yourselves make out some of the most important changes that are taking place on the floor of the sea.

8. For example, try to think what must become of the wasted rock that is every year carried from the surface of the land into the sea by rivers. What happens to it when it gets there? As it can descend no farther it must necessarily accumulate there. The land is undergoing a continual wearing away of its surface, from mountain-crest to sea-shore. The sea-bottom, on the other hand, is constantly receiving fresh materials on its surface.

9. The one is increased in proportion as the other is diminished. Even without knowing anything about what men have learned by means of deep soundings, you could confidently assert that every year there must be vast quantities of gravel, sand and mud laid down upon the floor of the sea, because these materials are worn away from the land.

10. In what way are these materials disposed of

when they reach the sea? As they are all brought from the land, they accumulate on those parts of the sea-floor which border the land, rather than at a distance. We may expect to find banks of sand and gravel in shallow seas, and near land, but not in the middle of the ocean.

1. How has the depth of the sea been ascertained?
2. In what ocean have most soundings been made?
3. How great a depth has been found?
4. How does this depth compare with the height of the highest mountains?
5. How have men learned the nature of the sea-floor?
6. How are the materials carried from the land into the sea disposed of?

LESSON XLVIII.

THE BOTTOM OF THE SEA.

II.

1. If you examine the channel of a river, in a season of drought, you may find, at one place, where the current has been strong, a bank of gravel. At another, where the currents of the river have met, perhaps there may be a ridge of sand that they have heaped up.

2. In those places where the flow of the stream has been more quiet and even, the channel may be covered with a layer of *silt*, or fine mud. The more powerful

a current of water, the larger will be the stones it can push along in its channel.

3. Coarse gravel, therefore, is not likely to be found over the bottom of the sea, except near the land, where the waves can sweep it out into the path of strong sea-currents. Sand will be carried farther out, and laid down in great sheets, or in banks. The silt may be borne by currents for hundreds of miles before finally settling down upon the sea-bottom.

4. But the sea is full of life, both of plants and animals. These organisms die, and their remains become mixed with the different materials laid down upon the sea-floor. Over the bottom of the sea, therefore, great beds of sand and mud, mingled with the remains of plants and animals, are always accumulating.

5. If, now, this floor could be raised up above the sea-level, the sand and mud would become as hard and dry as any rock among the hills. Still you would be able to say with certainty that they had once been under the sea, because you would find in them the shells and other remains of marine animals.

6. You will learn, when you come to study Geology, that this raising of the sea-bottom has often taken place in ancient times. You will then learn, too, that most of the rocks in our hills and valleys to-day were originally laid down in the sea.

7. They were formed out of sand and mud dropped on the sea-floor, just as sand and mud are carried out to sea and dropped there now. We sometimes find among them skeletons, and fragments of the various sea-creatures which were living in the old seas. And these are found, not merely on rocks near the shore, but far inland, in quarries or ravines, or on the sides, and even on the tops, of hills and mountains.

8. Since the bottom of the sea forms the great basin into which the moldered remains of the land are continually carried, if this process were to go on, without any change or hindrance, as long as the hills wear away and the rivers run down to the sea,—what must be the result?

9. It is plain that, in the end, the whole of the solid land would be worn away, and spread out on the sea-floor, leaving one vast ocean to roll round the entire globe. But there is, in nature, another force which here comes into operation to retard the destruction of the land. We must now see what that force is, and how it works.

1. What is silt?
2. Where is coarse gravel found on the bottom of the sea?
3. Why is it not found farther out?
4. What is found on the bottom of the deep sea?
5. How were many of the rocks on the land formed?
6. How is this shown?

LESSON XLIX.

THE INSIDE OF THE EARTH.

1. Thus far our attention has been given to the surface of the earth, and the changes taking place there. Let us now see what can be learned about the inside of the earth. It may seem at first as if it were hopeless that man should ever learn anything about the earth's interior.

2. So immense is this globe of ours that in living and moving about upon its surface we are merely like flies walking over a great hill All that can be seen from the top of the highest mountain to the bottom of the deepest mine is not more, in comparison, than the mere varnish on the outside of a school globe.

3. Yet much can be learned about what goes on within the earth. Here and there, in different countries, there are places where communication exists between the interior and the surface. It is by means of such places that much of our knowledge is obtained.

4. Volcanoes are among the most important of the channels of communication with the interior. Let us suppose that you were to visit a volcano just before what is called an eruption. As you approach it you see a conical mountain, seemingly with its top cut off.

From the summit rises a white cloud, not quite such, however, as you would see on a mountain top in this country.

5. As you watch it you notice that it rises out of the top of the mountain, even though there are no clouds to be seen anywhere else.

Ascending above the vegetation of the lower grounds, you find the slopes to consist partly of loose stones and ashes, and partly of rough, black sheets of rock.

6. As you get nearer the top, the ground feels hot, and puffs of steam, together with stifling vapors, come out of it here and there. At last you reach the summit. What seemed a level top is seen to be, in reality, a great basin, with steep walls descending into the depths of the mountain.

7. Screening your face, as much as possible, from the hot gases, which almost choke you, you creep to the top of this basin, and look down into it. Far below, at the base of the rough, red and yellow cliffs which form its sides, lies a pool of some liquid, glowing with a white heat, though covered, for the most part, with a black crust like that seen on the outside of the mountain during the ascent.

8. From this fiery pool, jets of red-hot liquid are thrown every now and then. Stones and dust are cast up into the air and fall back again. Clouds of steam

ascend from the same source, and form the uprising cloud which was seen hanging over the mountain.

9. This hollow on the summit of the mountain is the *Crater*. The intensely heated liquid in the boiling pool at its bottom, is melted rock, or *Lava*. The ashes, dust, cinders and stones thrown out, are torn from the hardened sides and bottom of the crater by the violence of the explosions with which the gases and steam escape.

10. The hot air and steam, and the melted mass at the bottom of the crater, show that there must be some source of intense heat underneath. As the heat has been coming out, at intervals, for hundreds, or even thousands of years, it must exist there in great abundance. When the volcano appears in active eruption, the power of this underground heat shows itself in the most marked manner.

11. For a day or two before, the ground around the mountain trembles. At length, in a series of violent explosions, the heart of the volcano is torn open, and perhaps its upper part is blown into the air. Huge clouds of steam roll up, mingled with fine dust, and red-hot stones.

12. The heavier stones fall back again into the crater, or on the outer slope of the mountain. The finer ashes come out in such quantity as sometimes to darken the sky for many miles around, and

settle down over the surrounding country as a thick covering.

13. Streams of white-hot molten lava run down the outside, even to the gardens and houses at the base, burning up or overflowing whatever lies in their path. This continues for days, or weeks, until the volcano exhausts itself. Then a time of comparative quiet comes, when only steam, hot vapors, and gases are given out.

1. How has anything been learned of the interior of the earth?
2. What are volcanoes?
3. What do the slopes of a volcano consist of?
4. What is the top?
5. What is this called?
6. What is thrown from it?
7. What is lava?

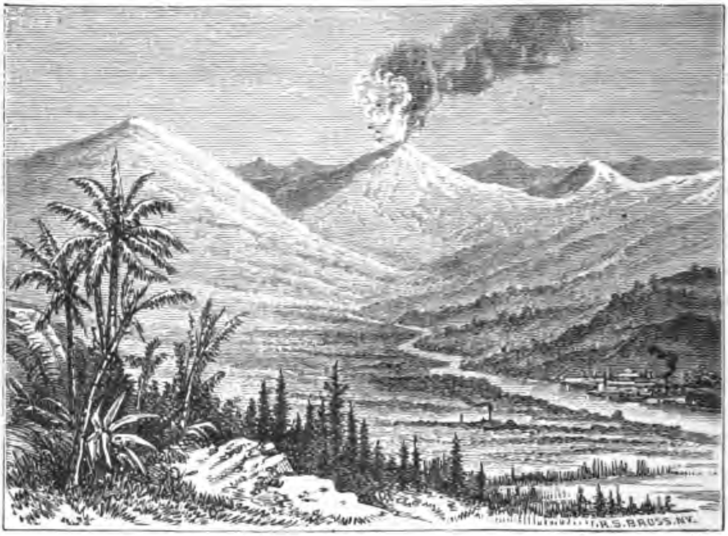
LESSON L.

VOLCANOES, GEYSERS, AND EARTHQUAKES.

1. Volcanoes mark the position of some of the openings through which heated materials from the inside of the earth are thrown up to the surface. They are found in all quarters of the globe. In Europe they are found in the basin of the Mediter

ranean, while, far to the northwest, some active volcanoes rise amid the snows and glaciers of Iceland.

2. In America a chain of huge volcanoes stretches down the range of mountains which rises on the western margin of the continent. In Asia they are



thickly grouped together on the island of Java, and on some of the surrounding islands. They stretch thence, through Japan and the Aleutian Isles, to the extremity of North America.

3. Since volcanoes are so numerous, we may conclude that the interior of the earth is intensely hot. But we have other proofs of this internal heat. In

many places *hot-springs* rise to the surface. Such springs are found, in this country, in Arkansas, Virginia, Colorado, and in some other parts.

4. A remarkable group of these hot-springs, called *geysers*, is found in Iceland, within sight of the volcano of Hecla. Numerous geysers occur in the western part of the Yellowstone National Park, mostly in Wyoming. Some of these throw out occasional jets of hot water to a height of two hundred fifty feet.

5. It is not merely by volcanoes and geysers, however, that the internal heat of the earth affects the surface. The solid ground is sometimes made to tremble, or is rent asunder, or upheaved, or lowered.

6. You have heard or read of *earthquakes*, those terrible shakings of the ground which, at their worst, crack the ground open, throw down trees and buildings, and sometimes bury hundreds or thousands of people in the ruins. They are most common in or near those countries where active volcanoes exist, and frequently take place just before a volcanic eruption.

7. Some parts of the land are slowly rising out of the sea; on the other hand, some tracts are slowly sinking. These movements, whether in an upward or downward direction, are due in some way to the internal heat. When you reflect upon these various changes you will see that, through the agency of this

internal heat, land is preserved upon the face of the earth.

8. If rain and frost, rivers, glaciers, and the sea, were to go on wearing down the surface of the land continually, without any counterbalancing action of this kind, the land would necessarily, in the end, disappear. Indeed it would have disappeared long ago but for what the internal heat has effected.

9. Owing to the pushing out of some parts of the earth's surface by the movement of the heated materials inside, portions of the land are raised to a higher level. Parts of the bed of the sea have been actually upheaved so as to form land, and this has happened many times in all quarters of the globe.

10. Let us now sum up the leading points of what we have learned about this earth of ours.

It is the scene of continual movement and change. The atmosphere which encircles it is always in motion, diffusing light, heat and vapor. From the sea, and from the waters of the land, vapor is constantly passing into the air. Condensed into clouds, rain, and snow, it falls again to the earth.

11. All over the surface of the land the water that falls from the sky courses seaward in brooks and rivers, bearing into the great deep the materials which have been worn away from the land. Water is thus ceaselessly circulating between the air, the land, and

the sea. The sea, too, is never at rest. Its waves wear away the edges of the land, and its currents sweep round the globe.

12. Into its depths the spoils of the land are borne, there to gather into rocks, out of which new continents and islands will eventually be formed. Lastly, inside the earth is lodged a vast store of heat, by which the surface is shaken, rent open, upraised, or depressed. Thus while old land is submerged beneath the sea, new tracts are upheaved, to be clothed with vegetation and peopled with animals and men.

13. This world is not a living being, like a plant or an animal, and yet you must now see that there is a sense in which we may speak of it as such. The circulation of air and water, the interchange of sea and land, the endless and continual movement by which the face of the globe is day by day altered and renewed, may well be spoken of as the Life of the Earth.

1. Where are volcanoes found?
2. What other proofs of internal heat have we?
3. Where are hot springs found?
4. Where are geysers found?
5. What are earthquakes?
6. Where are they most common?
7. By what are the elevations and depressions of the earth's surface caused?
8. What is the preservation of land on the face of the earth due to?

A VOCABULARY

OF THE MORE DIFFICULT WORDS, AND TERMS USED IN THIS BOOK

EXPLANATION.

n. means a noun. **a.** means an adjective.
v. " " verb. **adv.** " " adverb.

A.

ab străct′, *v.,* to draw from, or separate.

ab sôrb′, *v.,* to drink in, to suck up.

ac cū′mu lāte, *v.,* to heap up in a mass; to pile; to collect or bring together.

al tẽr′nate, *n.,* that which happens by turns with something else.

am mō′niȧ, *n.,* an alkali, having a pungent smell and taste.

ar tē′şian, *a.,* a kind of well, made by boring into the earth until the instrument reaches water, which then flows to the surface like a fountain. Artesian wells are usually of great depth.

är′ti fĭ′cial, *a.,* made or contrived by art, or by human skill, as distinguished from what exists by nature.

är′ti şan, *n.,* one who does mechanical work. A portrait painter is an *artist*, a sign painter is an *artisan*

ăt′om, *n.,* a particle of matter so small as to be regarded as indivisible.

ăt′mos phēre, *n.,* the whole mass of the fluid, which we call air, surrounding the earth.

a̤wn′ing, *n.,* a cover intended to shelter.

C.

canōn (kan′-yŭn), *n.,* a deep gorge, ravine, or gulch, worn by water-courses, between high and steep banks.

cär′bon, *n.,* an elementary substance found in all organic compounds. It is combustible, that is, it will burn. It forms the base of charcoal, and enters largely into coal. In its pure crystallized

state it constitutes the brilliant diamond.

car bŏn′ic, *a.*, of, or pertaining to, carbon,

chăsm (kăzm), *n.*, a deep opening made in the earth, or in rock; a cleft.

çir′cu lā′tion, *n.*, the act of moving in a circle, or in a course which tends to bring the moving body to the place where its motion began.

cloud′let, *n.*, a small cloud.

com mem′o rāte, *v.*, to call to remembrance.

con dĕnse′, *v.*, to make more close; to compress into a smaller compass. To reduce to another and more compact form.

con dŭct′, *v.*, to lead, or to guide.

con trăc′tion, *n.*, the act of drawing together; the act of lessening extent, or dimensions.

con vērt′, *v.*, to change or turn from one state or condition to another.

crā′ter, *n.*, the aperture or mouth of a volcano.

cre văsse′, *n.*, a deep crack or split; one of the clefts by which a glacier is divided.

crȳs′tal, *n.*, the regular form which a substance tends to assume in becoming solid. It is bounded by plane surfaces.

çȳ′clone, *n.*, a storm which moves around a center; a whirlwind of very large circuit.

D.

dē com poşe′, *v.*, to separate the parts of; to set free from previously existing forms of combination; to resolve into original elements.

de lĭ′cioŭs (de lĭsh′us) *a.*, delightful; grateful to the senses.

dĕl′tȧ, *n.*, a tract of land similar to the Greek letter Δ delta, formed between the two mouths of a river.

dĭ min′ish, *v.*, to make smaller in any manner; to reduce in bulk, or amount.

dis tin̲′guish (ting-guish), *v.*, to separate or recognize by visible marks.

E.

eärth′quāke, *n.*, a shaking, or a trembling of the earth, due to causes at work under the surface. It is often accompanied by a rumbling noise.

ē quā′tor, *n.*, a great circle on the earth's surface, equally distant from the two poles. It divides the earth into the northern and southern hemispheres.

ē′qua tō′rial, *a.*, pertaining to the equator.

e rŭp′tion, *n.*, the act of bursting, or breaking forth.

e văp′o rā′tion, *n.*, the act or process of turning into, or passing off in vapor.

ex pan'sion (eks păn'shun), *n.*, the act of spreading out.

ex pĕr'i ment, *n.*, a trial; an act or operation undertaken to find out something unknown, or to prove something.

ex plō'şion (eks-plō'zhun), *n.*, the act of exploding or bursting with a loud noise.

F.

fau'çet *n.*, a fixture for drawing liquid from a cask or vessel, or for drawing water from a pipe.

fī'bre, *n.*, any fine, slender thread, or thread-like substance.

freight (frāt), *n.*, that with which any thing is laden.

G.

găş'e oŭs (găz e ŭs), *a.*, in the form of gas.

ḡeȳ'ser (ḡī'ser), *n.*, a natural fountain which spouts forth boiling water.

ġī găn'tic, *a.*, of extraordinary size; very large; enormous.

glā'çier (glā'-seer or glăs'-ĭ-er), *n.*, a field, or immense field of ice or of snow and ice, formed in the region of perpetual snow.

gôrġe, *n.*, a narrow passage or entrance between mountains.

grăv'i ty, *n.*, weight; heaviness.

grăv i tā'tion, *n.*, that force, in nature, by which all particles of matter tend toward each other.

H.

hĕm'i sphēre, *n.*, half a sphere. Half of any globe.

hȳ'dro ġen, *n.*, a gas which constitutes one of the elements of water. It is very light, and without color.

I.

īçe'bĕrg, *n.*, a hill, or mountain of ice; a vast and lofty body of ice floating on the ocean.

in scrĭp'tion (in-skrĭp'-shun), *n.*, any thing written or engraved on a solid substance.

ĭn'ter mit'tent, *a.*, ceasing at intervals.

in vĭş i ble (in-vĭz-ĭ-bl), *a.*, that which cannot be seen.

L.

lā'vȧ, or lä'vȧ, *n.*, the melted rock thrown out from the crater of a volcano.

M.

ma tē'ri al, *a.*, consisting of matter.

ma rïne' (ma-reen'), *a.*, pertaining or relating to the sea.

me chăn'i cal, *a.*, pertaining to or governed by, or in accordance with mechanics; depending upon mechanism.

mĕs'sen ġer, *n.*, one who bears a message, or an errand.

mī'cro scōpe, *n.*, an instrument consisting of a lens or a combination of lenses for examining objects

too small to be seen by the naked eye.

mĭ nūte′, *a.*, very small; very slender.

mo rāine′, *n.*, a line of rocks and gravel extending along the sides of separate glaciers, or along the middle part of a glacier formed by the union of separate glaciers.

N.

nī′tro ġen, *n.*, a gaseous element without taste, odor, or color, forming nearly four-fifths of common air.

O.

ŏb′ṣer vā′tion, *n.*, the act or power of taking notice, or seeing.

ôr′gan ĭṣm, *n.*, a structure composed of, or acting by means of organs.

ŏx′y ġen, *n.*, a gas destitute, in its ordinary condition, of taste, color, or smell. It serves to support life and forms a trifle over one-fifth of the atmosphere.

P.

pär′ti cle, *n.*, a very small substance, or part of matter.

pe cūl iar′i ty (pe-kūl-yăr-ĭ-tў), *n.*, the quality of being special or distinctive.

per çēive′, *v.*, to gain knowledge through the senses.

per çĕp′ti ble, *a.*, capable of being known through the senses.

pĕr′ma nent, *a.*, continuing without change.

pĕr′vi oŭs, *a.*, capable of being penetrated by another body or substance.

phĭ lŏs′o pher, *n.*, one devoted to philosophy.

pĭct ūr ĕsque′ (pĭkt-yụr-ĕsk′), *a.*, fitted to form a good and pleasing picture.

prē çede′, *v.*, to go before in place, or in order of time; to occur first.

prĕç′i pĭçe, *n.*, very steep, or overhanging place.

prŏm′on to ry, *n.*, a high point of land or rock projecting into the water beyond the line of the coast.

pro pĕl′, *v.*, to drive forward; to urge or press onward.

R.

rā′di ā′tion, *n.*, emission and diffusion of rays of light.

ra vīne′ (ra-vēn′), *n.*, a deep and narrow hollow, usually worn by a stream of water.

re çĕp′ta cle, *n.*, that which receives, or that into which anything is received and held.

rĕṣ′er voir′(rĕz′-er-vwôr′), *n.*, a place where anything is kept in store, especially a place where water is collected and kept for use.

re ṣist′ance, *n.*, the act of not yielding to force or external impression.

S.

sçī'ençe, *n.*, knowledge properly classified.

sçī'en tĭf'ic, *a.*, pertaining to science; agreeing with science.

sen sā'tion, *n.*, an impression made upon the mind by external objects, through the senses.

sĕn'seş, *n.*, the bodily organs through which the mind gains knowledge of the outer world, as the sense of hearing, sight, taste, touch, smell.

sŏl'i ta ry, *a.*, destitute of associates; being by one's self.

so lū'tion, *n.*, the act of separating the parts of any body. To hold in solution is to contain the parts of another substance.

strēam'let, *n.*, a small stream; a rivulet; a rill.

sub mĕrġ'ed, *v.*, being under water; covered or overflowed with water.

sŭb'ter rā'ne an, *a.*, being or lying under the surface of the earth; underground.

suc çĕs'sive, *a.*, following in order, or in uninterrupted course; coming after without interruption.

T.

tĕm'per a tūre, *n.*, condition of a body with respect to degree of heat or cold.

tĕnd'en çy, *n.*, direction or course toward any place, object, fact, or result; drift.

tĕr'raçe, *n.*, a level spot or platform of earth, either raised, or made by cutting down surrounding earth.

trans pâr'ent, *a.*, having the property of admitting the passage of rays of light.

trans pâr'en çy, *n.*, quality of being clear or transparent.

trăv'erse, *v.*, to lay in a cross direction; to cross.

tŭn'nel, *n.*, an arch, or passage underneath.

U.

ū'ni vērse, *n.*, all created things considered as making one system. Often used to denote merely the whole of this world.

V.

vol cā'no, *n.*, a mountain from which lava, steam, sulphurous gases and the like are thrown out.

vol căn'ic, *a.*, pertaining to a volcano.

W.

wāve'let, *n.*, a small wave; a ripple.